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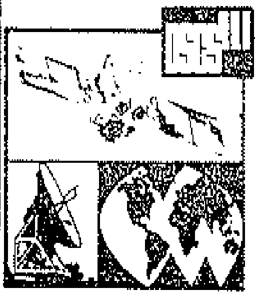
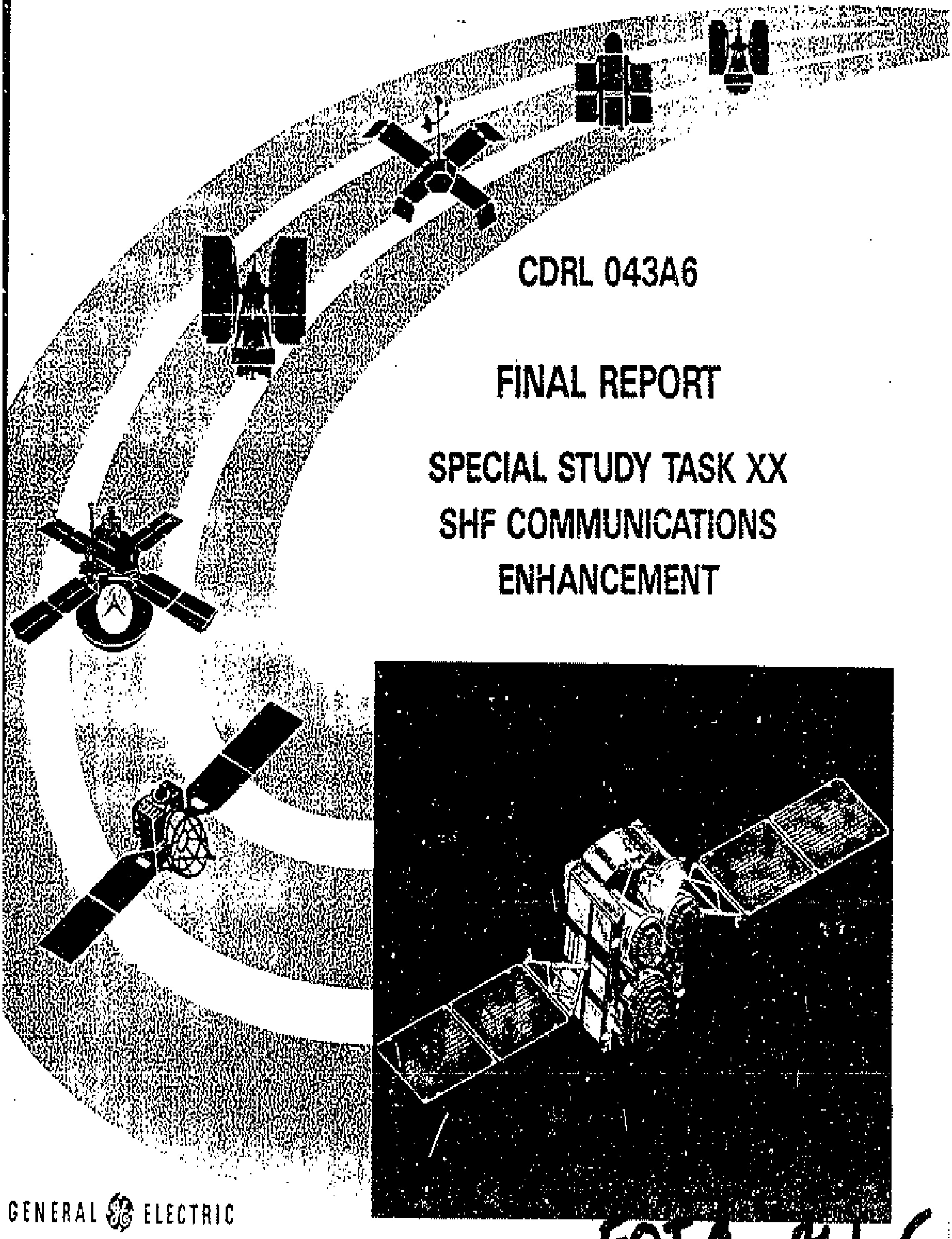


DEFENSE SATELLITE COMMUNICATIONS SYSTEM

CDRL 043A6

FINAL REPORT

SPECIAL STUDY TASK XX
SHF COMMUNICATIONS
ENHANCEMENT



GENERAL ELECTRIC
SPACE SYSTEMS DIVISION

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DOCUMENT NO. 86SDS4252
JUNE 1986

DEFENSE SATELLITE COMMUNICATION SYSTEMS

PHASE 3 PROGRAM

FOLLOW ON PRODUCTION

CDRL 043A5

FINAL REPORT

SPECIAL STUDY TASK XX
SHF COMMUNICATIONS
ENHANCEMENT

Prepared for
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INTRODUCTION AND SUMMARY

SECTION 1

INTRODUCTION AND SUMMARY

This report covers the results of a study conducted in January through May of 1986 on SHF Enhancements for the DSCS III satellites. These enhancements are aimed at providing increased coverage, data, and protection capability for the various communications services using the DSCS III system.

Improved antenna flexibility and gain characteristics, improved linear transmit power, and improved power monitoring and phase noise characteristics are benefits to be gained from the enhancements studied.

Implementation on certain of the seven Multi-year Procurement (MYP) satellites is anticipated, as well as on future procurements (B15 and beyond) that may use SHF. Possible points of introduction are discussed throughout this report.

The Statement of Work for this study is included for reference purposes as Appendix A.

This study required utilization of a broad range of system and design engineering disciplines, as well as cost estimates from many additional areas. It was not possible to address in detail promising new ideas developed during the study. These are, therefore, summarized in the "Recommendations for Further Effort" section.

The initial Section of this report is largely in briefing chart format. Thus, it can serve as a condensed overview, or for incorporation into presentations. Further details and explanations may be found in subsequent narratives.

1.1 SUMMARY OF SELECTED APPROACHES

The following charts briefly summarize the selected approach for each of the options studied. The more significant advantages from each concept are also shown.

SPACE SYSTEMS DIVISION

OPTION A - ADDITIONAL GDA

SELECTED APPROACH

- TWO FLIP-UP OFFSET REFLECTORS ON "BACK" OF SPACECRAFT
- FIXED FEED - REQUIRES LESS WAVEGUIDE, NO ROTARY JOINTS
- WEIGHT IMPACT TOLERABLE: + 27 POUNDS
- MINOR HEATER POWER IMPACT
- OFFSET FEATURE ELIMINATES FEED BLOCKAGE
- USE OF DSCS QUALIFIED MECHANISMS ANTICIPATED
- GDA POWER SPLITTER CAN BE FIXED DIVIDER, VARIABLE DIVIDER OR FILTER NETWORK (MOST PROMISING)
- CURRENT GDA DESIGN WOULD BE ELIMINATED, BUT ALL FUNCTIONS PRESERVED

OPTION B - MULTIMODE EARTH COVERAGE HORN

- SELECTED APPROACH IS A 7.6 WAVELENGTH APERTURE (12")
- INCREASED GAIN OVER 59% OF THE EARTH IS PROVIDED
- LARGER APERTURES DO NOT FIT UNLESS OTHER CHANGES ARE MADE (I.E., SCT ANTENNA REDESIGN OR MBA DELETION)
- 4 LBS/HORN WEIGHT INCREASE
- MULTIMODE EXCITATION IS PROVIDED BY WELL UNDERSTOOD TECHNIQUES

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OPTION C - KIDNEY BEAM ANTENNA

- SELECTED APPROACH IS AN OFFSET REFLECTOR FED BY A FOUR HORN CLUSTER
- COVERAGE FOR ALL SATELLITE LOCATIONS IS PROVIDED BASED ON TYPICAL REQUIREMENTS PROVIDED BY DCEC
- RELIABILITY LIKELY TO BE HIGHER THAN MECHANICALLY POSITIONED HORN DUE TO ALL-ELECTRONIC FEED NETWORK
- WEIGHT AND SPACE WOULD BE SAVED COMPARED WITH CURRENT MBA
- VARIOUS FEED NETWORK OPTIONS USING VPDs OR SWITCHES ARE POSSIBLE TO PROVIDE VARYING PATTERN FLEXIBILITY

OPTION D - ALL ANTENNA UPGRADES

- MIX REMOVED

  - ALLOWS SUBSTANTIAL WEIGHT SAVINGS WHEN KIDNEY BEAM ANTENNA IS SUBSTITUTED

  - ROOM IS PROVIDED FOR ALTERNATE ANTENNA CONCEPTS - POSSIBLY GDA OR LARGER EARTH COVERAGE HORNS

  - WEIGHT CAN BE USED FOR ALTERNATE SHF ENHANCEMENTS OR OTHER SATELLITE UPGRADES

SPACE SYSTEMS DIVISION

OPTION F - ULTRA LINEAR SSA

- SELECTED APPROACH
  - ULSSA WITH: 16 WATT RF OUTPUT - SATURATED MODE
    10 WATT RF OUTPUT - LINEAR MODE
  - AUTOMATIC OR COMMANDABLE RF POWER LIMITING
  - REPLACES 10 WATT HESSA
- SIGNIFICANT ADVANTAGES
  - IMPROVED RF POWER OUTPUT - +2.5 dB FOR SAT. OPERATION
  - 2.7 dB IMPROVEMENT IN TWO TONE, THIRD ORDER IMD AT 39.7 dBm
  - NO IMPACT ON STRUCTURAL OR THERMAL DESIGNS
  - POWER IMPACT
    - NO IMPACT FOR LINEAR OPERATION
    - SATURATED OPERATION POWER AVAILABLE AT MISSION BEGINNING FROM EXCESS POWER NORMALLY OFF LOADED TO DISSIPATORS

OPTION G - LINEARIZING DEVICE

- SELECTED APPROACH
  - DUAL-GATE FET, SMALL SIGNAL PREDISTORTION DEVICE
  - TRANSFER CHARACTERISTIC COMPLEMENTARY TO TRANSMIT AMPLIFIERS
  - LINEARIZES OUTPUT OF FOLLOWING AMPLIFIERS
- SIGNIFICANT ADVANTAGES
  - INCREASED LINEAR RF OUTPUT POWER
  - IMPROVED IMD PERFORMANCE AT P_{SAT}-3 dB AND P_{SAT}-6 dB
  - INCREASED TRAFFIC HANDLING CAPACITY (1 dB ESTIMATED EQUIVALENT EIRP IMPROVEMENT)
  - NOMINAL IMPACT ON STRUCTURAL, THERMAL, AND POWER DESIGNS

SPACE SYSTEMS DIVISION

OPTION H - TLS ACCURACY IMPROVEMENT

OPTION 1: NOISE CALIBRATION TECHNIQUE WITH SOFTWARE TEMPERATURE INTERPOLATION

- SATURATION - 2 dB TO SAT - 10 dB
- OP-HIGH TO OP-LOW TEMPERATURE RANGE
- ±1 dB ACCURACY

OPTION 2: ABOVE CALIBRATION TECHNIQUE COUPLED WITH HARDWARE 2ND HARMONIC FILTERING

- SAT TO SAT - 10 dB
- OP-HIGH TO OP-LOW TEMPERATURE RANGE
- ±1 dB ACCURACY

SPACE SYSTEMS DIVISION

OPTION I - VCO IMPROVEMENT

- SELECTED APPROACH
  - VCO IMPROVEMENT BASED ON SURFACE ACOUSTIC WAVE (SAW) DELAY LINE TECHNOLOGY
  - REDUCED MECHANICAL TUNING
  - PHYSICALLY REPLACES PRESENT DEVICE
- SIGNIFICANT ADVANTAGES
  - IMPROVED WIDEBAND NOISE PERFORMANCE
  - REDUCED MICROPHONIC SUSCEPTIBILITY
  - INTEGRATION REQUIRES MAXIMUM CHANGE OF FIVE CAPACITORS AND RESISTORS
  - IMPROVED LONG-TERM STABILITY
  - REDUCED SUSCEPTIBILITY TO EMI

1.2 BENEFITS AND IMPACTS SUMMARY

The following charts show the benefits and impacts for each of the options studied. Impacts in the spacecraft and SCCE are noted, along with any operational constraints.

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: ADDITIONAL GDA (A)

	BENEFITS	PENALTIES
USER:	• MULTIPLE COVERAGES IN SAME CHANNEL (SPECIFIC GMF) • NO CONFLICT FOR HIGH GAIN D/L BETWEEN GMF, TACIES, WHCH	• SOME OUTPUT POWER LOST WHEN BOTH ON • BOTH ANTENNAS CANNOT BE TARGETTED AT SAME AREA • FREQUENCY REUSE REDUCES EFFECTIVE EIRP UNLESS CHANNEL IS SPLIT BY OUTPUT FILTERING
S/C	NONE	• ADDED WEIGHT • ADDED CMD TO ACE ADDITIONAL TLM (ENCODER) • WEIGHT/THERMAL BALANCE REDO • HEATER POWER REQUIRED
SCCE	NONE	• DUPLICATE CMD GDA #1, #2 • ADDED TLM PROCESSING • ADDED CONFIGURATION MGT OF TWO ANTENNAS

OPERATIONAL CONSTRAINTS: • ANTENNA TARGETTING (WITH BOTH ANTENNAS ON) MUST MAINTAIN 2-3 BW SEPARATION FOR INTERFERMETER EFFECT

COMMENTS: ASSUME: SAME AS CURRENT GDA (33"); SAME CONNECTIVITY OF EXISTING UNIT

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: MULTI-MODE EC HORN (B)

	BENEFITS	PENALTIES
USER:	• ADDED DIRECTIVE GAIN CH 3-6 • POTENTIALLY ADDED THRUPUT IN THESE CHANGES	• POTENTIAL GAIN LOSS AT SUB SATELLITE POINT • NEW ALLOCATION S/W NEEDED
S/C	• NONE	• SLIGHT WEIGHT INCREASE • GAIN STABILITY NEEDS TO BE EVALUATED • SPECS NEED TO BE UPDATED
SCCE	• ADDED BEACON EIRP (MAY HELP SCINTILLATION)	• NEW ANTENNA PATTERN S/W NEEDED • ALL CUSTOMER S/W MUST BE UPDATED WITH NEW COVERAGE ALGORITHM

OPERATIONAL CONSTRAINTS:

MUST RECALCULATE BEACON POWER FLUX DENSITY TO INSURE COMPLIANCE WITH TICP REQUIREMENTS FOR POWER SPECTRUM DENSITY (FUNCTION OF ANGLE ABOVE HORIZON)

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: STEERABLE KIDNEY COVERAGE ANTENNA (C)

	BENEFITS	PENALTIES
USER:	• MORE EIRP IN CHANNELS 1/3 IN NOMINAL STATE • MORE THRUPUT DUE TO BW/PWR/CODING TRADES • LESS COMPLEX ALLOCATION ALGORITHM	• LESS COVERAGE FLEXIBILITY • LOSE SPOT MODE EIRP • RESTRICTS CHANNEL USER TO AREA BEING COVERED
S/C	• LESS WEIGHT ANTENNA SPACE • SPACE AVAILABLE IN CENTER-BODY • REDUCED ACE/BFN HW/SW	• NEW FEED NETWORK AND HORNS REQUIRED • NEW CMD/TLM IF • NEW STRUCTURE REQUIRED
SCCE:	• POSSIBLY SIMPLIFIED POINTING ALGORITHM	• OPTIMUM POINT ALGORITHM DEV. • ADDED CMDS TO POINT ANTENNA • NEW PATTERN ALGORITHM • DISPLAY MODIFICATION FOR NEW NOMENCLATURE

OPERATIONAL CONSTRAINTS:
USERS MUST BE COVERED AREA

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: MBX REMOVAL (D)

	BENEFITS	PENALTIES
USER:	• DEPENDENT ON REPLACEMENT SEE A, B, C	• LESS FLEXIBILITY IN COVERAGE • SEE A, B, C
S/C:	• WEIGHT/POWER AVAILABLE FOR OTHER CONCEPTS • SPACE AVAILABLE FOR OTHER UNITS (E. G., GDA)	• THERMAL/WEIGHT BALANCING REDO • STRUCTURE REDESIGNS OR REQUAL FOR NEW CONFIGURATION
SCCE:	• REDUCED PROCESSOR LOAD FOR 2 MBX DATA BASES, ALGORITHMS AND CMDS	• SEE A, B, C

OPERATIONAL CONSTRAINTS:
NONE (SEE ITEMS A, B, C

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: PWR SPLITTER MBX/GDA (E) (THIS OPTION WAS DELETED EARLY IN THE STUDY)

	BENEFITS	PENALTIES
USER:	• ADDED FLEXIBILITY IN COVERING WIDELY SEPARATED USERS. • ADDED EIRP TO GDA USERS OVER THAT AVAILABLE IN MBX • ADDED THRUPUT POSSIBLE	• RESTRICTED POINTING TO PREVENT INTER-FEROMETER EFFECTS • FREQ REUSE PROHIBITION, INTERFERING/CLEARANCES • NOT AVAILABLE TO ALL CHANNELS (?) • ISOLATION BETWEEN MBX/GDA IN 1/0 OR 0/1 MODE
S/C:	NONE	• ADDED H/W ON NORTH PANEL (NEW DRIVER, ETC) • MOD NP PWR CONTROLLER • ACE MODES
SCCE:	NONE	• NEW SW TO HANDLE SWITCH LOGIC • ADDED CMDS/TLM

OPERATIONAL CONSTRAINTS:
CANNOT POINT GDA/MBX AT SAME LOCATION; A TBD ANGLE SEPARATION MUST BE MAINTAINED

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: 10-WATT ULTRA-LINEAR SSA (F)

	BENEFITS	PENALTIES
USER:	• LOWER IM's AT SAME RELATIVE OUTPUT POWER OF TWTA • C/I IMPROVEMENT • MORE LINEAR POWER AVAILABLE • 50-100% POTENTIAL CAPACITY IMPROVEMENT IN PWR LIMITED CASES	• AVALANCHE HAPPENS QUICKER AND FASTER DUE TO OPERATING POINT OF TRANSPONDER
S/C:	• AT BOL MORE S/A POWER USED IN TRANSPONDER VS. DISSIPATED IN HEAT	• FETAL MUST BE MODIFIED • THERMAL BALANCE MAY BE IMPACTED • OVERLOAD PROTECTION (ON RF INPUT) NEEDED
SCCE:	NONE	• ADDED CMDS FOR OVERLOAD PROTECT INTER-LOCK

OPERATIONAL CONSTRAINTS:
NEED TO MIX THE SSA POPULATION BETWEEN UL AND STD UNITS TO MAINTAIN POWER BALANCE OR RESTRICT OPERATION IN POWER DEGRADED EOL STATE

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: LINEARIZER DEVICE (G)

	BENEFITS	PENALTIES
USER:	• LOWER ACTIVE IM's IN TRANSPONDER • IMPROVED C/I AND PWR ROBBING (ALSO AM/PM LINEARITY BETTER) • CARRIERS CAN BE PLACED CLOSER TOGETHER • FREQ. PLANNING PROBLEMS REDUCED	• MAY NOT GIVE DRAMATIC REDUCTION AT 2-3 dB B.O. • ADDITIONAL DEVICE - COULD REDUCE RELIABILITY • CDMA/SATURATED OPERATION MAY BE IMPACTED (SATURATED TOTAL PHASE SHIFT)
S/C	COULD ACHIEVE EQUIVALENT PERFORMANCE TO SSA-UL WITHOUT PRIME POWER INCREASE	• ADDITIONAL SUBASSEMBLY TO MATE INTO NORTH PANEL • FMEA ON CHANNEL PERFORMANCE NEEDED
SCCE:	NONE	NONE

OPERATIONAL CONSTRAINTS:
MAY WANT TO SWITCH IN/OUT AS FUNCTION OF CHANNEL OPERATION TYPE

SHF ENHANCEMENT SUMMARY

CONCEPT: TRANSMIT LEVEL SENSOR (H)

	BENEFITS	PENALTIES
USER:	• BETTER KNOWLEDGE OF CHANNEL OPERATION FOR CONTROL SYSTEM • LESS A FUNCTION OF WAVEFORM WITH NOISE CALIBRATION	
S/C:	• BETTER DETERMINATION OF TWTA/SSA OUTPUT POWER	
SCCE:		

OPERATIONAL CONSTRAINTS:

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT SUMMARY

CONCEPT: IMP VCO (200/725 MHz) (I)

	BENEFITS	PENALTIES
USER:	• LESS PHASE NOISE	
S/C:	• LESS MANUFACTURING/TEST TIME • LESS LIKELIHOOD OF NEEDING RETEST • IMPROVED RELIABILITY • IMPROVED EMI IMMUNITY	REQUAL BOX/BOARDS WITH NEW UNITS
SCCE:		N/A

OPERATIONAL CONSTRAINTS: NONE

1.3 ROM COSTING SUMMARY

ROM (Rough Order of Magnitude) price estimates for each of the options studied are shown in the charts that follow. Estimates for Development and Production are identified separately by Government Fiscal Year. Parts and materials are included as appropriate in each category.

It is assumed that the development effort and long lead parts procurement would be authorized to start October 1, 1986. The ground rules applicable to each cost category are noted, along with relevant observations in the case or the production costs.

The prices shown are stand-alone. Thus some savings may be possible by selection of various options in combination where certain tasks would not have to be duplicated. Because of the wide variety of possible attractive combinations, the possibility of new options and the nature of ROM estimates it was not attempted to specifically identify such savings.

The costs for retrofit of new enhanced hardware into vehicles that are either finished of partly finished the manufacturing and test cycle are not shown. As noted, it is projected that B14 implementation will be possible without retrofit. The production costs shown are thus related to new replacement component fabrication and test, since it is not projected that any significant benefit can accrue (in most cases) from rebuilding or interrupting current component production.

For component quantities beyond those shown, it is expected that the overall material and parts related cost will drop considerably, on a per component basis. This is due to the fact that all subcontract/purchase order placement and lot charges are shown against the initial unit.

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT DEVELOPMENT COST GROUNDRULES

- "THEN - YEAR" DOLLARS USED.
- ALL SUPPORT AND PROJECT ADMINISTRATION INCLUDED.
- ALL NON-RECURRING TASKS INCLUDED. E.G:
  - MOCK UPS/HARNESS BOARDS
  - SYSTEM INTEGRATION DESIGN AND ANALYSIS
  - ALL PDR/CDR ACTIVITY
- ALL MATERIALS AND PARTS FOR DEVELOPMENT AND ENGINEERING MODELS INCLUDED.
- TESTING (TO QUAL LEVELS) OF ENGINEERING MODELS (ONE FOR EACH OPTION) INCLUDED.
- NO SDM

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT DEVELOPMENT COST SUMMARY

OPTION	ROM TARGET PRICE
A) ADDITIONAL GIMBALLED DISH ANTENNA	$5.8 MILLION
B) MULTIMODE EARTH COVERAGE HORM	$1.4 MILLION
C) KIDNEY BEAM ANTENNA	$5.2 MILLION
D) REMOVAL OF M1X	INCLUDED IN (C) ABOVE.
E) VARIABLE RF POWER SPLITTER BETWEEN THE GDA AND MBX IN CHANNEL 2	• OPTION DROPPED AT KICK-OFF MEETING • VARIABLE POWER SPLITTER COSTS ARE INCLUDED IN OPTION (A) ABOVE
F) ULTRALINEAR SSA FOR 10W CHANNELS	$6.8 MILLION
G) LINEARIZING DEVICE FOR ALL CHANNELS	$3.1 MILLION
H) TRANSMIT LEVEL SENSOR (TLS) ACCURACY IMPROVEMENT	$.8 MILLION
I) IMPROVED 200 MHz AND 725 MHz VOLTAGE CONTROLLED OSCILLATORS	$1.0 MILLION

SHF ENHANCEMENT PRODUCTION COST
GROUNDRULES/OBSERVATIONS

- COST ESTIMATES INCLUDE FABRICATION AND FULL ACCEPTANCE TESTS OF HARDWARE QUANTITIES SHOWN.
  - REWORK OF COMPLETED OR PARTIALLY COMPLETED COMPONENTS IS <u>NOT</u> ASSUMED.
  - IF A NEW COMPONENT REPLACES AN EXISTING ONE, IT IS ASSUMED THE REPLACED COMPONENTS WOULD BE HELD AS A SPARE.
- ANY RETEST COSTS AT THE NORTH PANEL OR SYSTEM LEVEL IS NOT INCLUDED SINCE IT IS ASSUMED THAT THE CHANGES WILL BE INITIATED IN A TIMELY MANNER TO ALLOW COMPONENT INTEGRATION WITHIN THE CURRENT B14 SCHEDULE. FOR EARLIER VEHICLES A DELAY OR REWORK/RETEST ARRANGEMENT WOULD BE NECESSARY.
- MODIFICATION OF SYSTEM TEST PLANS AND PROCEDURES AND ADDITIONAL TEST COMPLEXITY - IF APPLICABLE - HAS NOT BEEN INCLUDED.

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT PRODUCTION COST GROUNDRULES/OBSERVATIONS (CONT'D)

- USE OF ENHANCEMENTS ON FUTURE (B15 -) VEHICLES WOULD REQUIRE SIGNIFICANTLY LESS THAN THE REPLACEMENT COSTS QUOTED.

- ALL PARTS, MATERIALS, SUBCONTRACTS AND RELATED SUPPORT ARE INCLUDED. INITIAL LOT CHARGES AND SPECIAL TESTING ARE INCLUDED (AS A RESULT ULTRALINEAR SSA COSTS ARE SIGNIFICANTLY MATERIAL RELATED; SUBSEQUENT UNITS WILL BE LESS COSTLY).

- QUANTITIES USED ARE GENERALLY BASED ON DISCUSSIONS WITH AF/DCA AS TO DESIRED CONFIGURATIONS.

SPACE SYSTEMS DIVISION

SHF ENHANCEMENT PRODUCTION COST SUMMARY

OPTION	QUANTITY	ROM TARGET PRICE
A) ADDITIONAL GIMBALLED DISH ANTENNA	2	$3.7 MILLION
B) MULTIMODE EARTH COVERAGE HORM	2	$0.4 MILLION
C) KIDNEY BEAM ANTENNA	1	$2.4 MILLION
D) REMOVAL OF M1X	-	UNIT REMOVED WOULD BECOME A SPARE
E) VARIABLE RF POWER SPLITTER BETWEEN THE GDA AND MBX IN CHANNEL 2	-	
F) ULTRALINEAR SSA FOR 10W CHANNELS	3	$6.3 MILLION
G) LINEARIZING DEVICE FOR ALL CHANNELS	10	$2.4 MILLION
H) TRANSMIT LEVEL SENSOR (TLS) ACCURACY IMPROVEMENT	6	$.8 MILLION
I) IMPROVED 200 MHz AND 725 MHz VOLTAGE CONTROLLED OSCILLATORS	4 VCO'S (1 FREQ GEN)	$1.1 MILLION

SPACE SYSTEMS DIVISION

SHF ENHANCEMENTS
GFY FUNDING REQUIREMENTS

OPTION			1987	1988	1989	TOTAL
A)	GDA	(D)	4057.0	1721.0	-	5778.0
		(P)	1246.0	1609.0	797.0	3652.0
B)	ECH	(D)	952.0	399.0	-	1351.0
		(P)	23.0	236.0	118.0	377.0
C)	KBA	(D)	3651.0	1549.0	-	5200.0
		(P)	1246.0	805.0	398.0	2449.0
F)	USSA	(D)	4700.0	2079.0	-	6779.0
		(P)	2298.0	2644.0	1318.0	6260.0
G)	LD	(D)	2218.0	908.0	-	3126.0
		(P)	624.0	1182.0	587.0	2393.0
H)	TLS	(D)	509.0	241.0	-	750.0
		(P)	208.0	378.0	189.0	775.0
I)	VCO	(D)	731.0	310.0	-	1041.0
		(P)	831.0	189.0	94.0	1114.0

1.4 SCHEDULE AND IMPLEMENTATION SUMMARY

For reference purposes, the overall DSCS Multi Year Schedule (B8-B14 Spacecraft) is shown as Figure 1-1. Based on this schedule, together with the assumption that enhancement hardware must be ready by the start-of-assembly-date for the applicable spacecraft sub-assembly (i.e. North Powel, Center Body, etc.), the following points of introduction are possible:

Enhancement	Vehicle First Used
Additional GDA	B14
Multi Mode Earth Coverage Horn	*B14
Kidney Beam Antenna	B14
Above enhancements, less MIX	B14
Ultra Linear SSA	B14
Linearizer	B14
TLS	B14
VCO's	*B14

Release of long lead hardware prior to CDR is assumed in cases where appropriate. *Initially it was hoped that the Earth Coverage Horns and VCO's could be ready for B13, but since long and uncertain vendor procurements are involved, first use on B14 has been conservatively selected.

Military Uses of Space: 1946-1991

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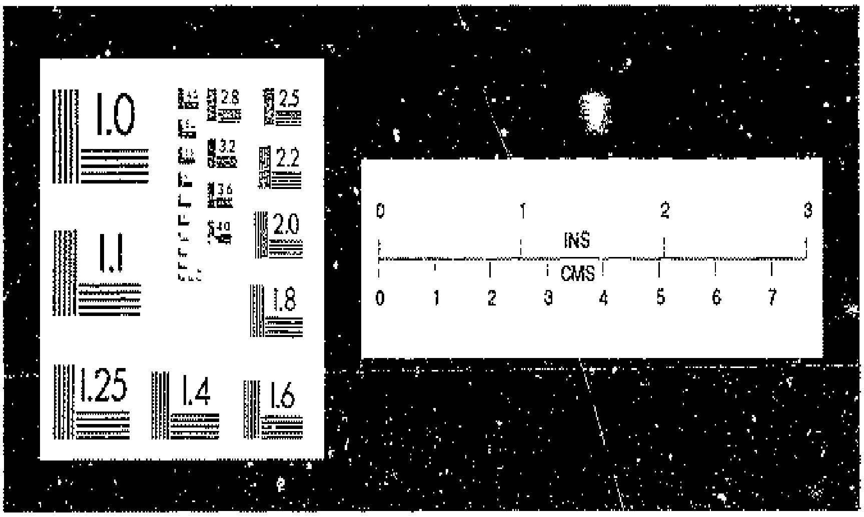

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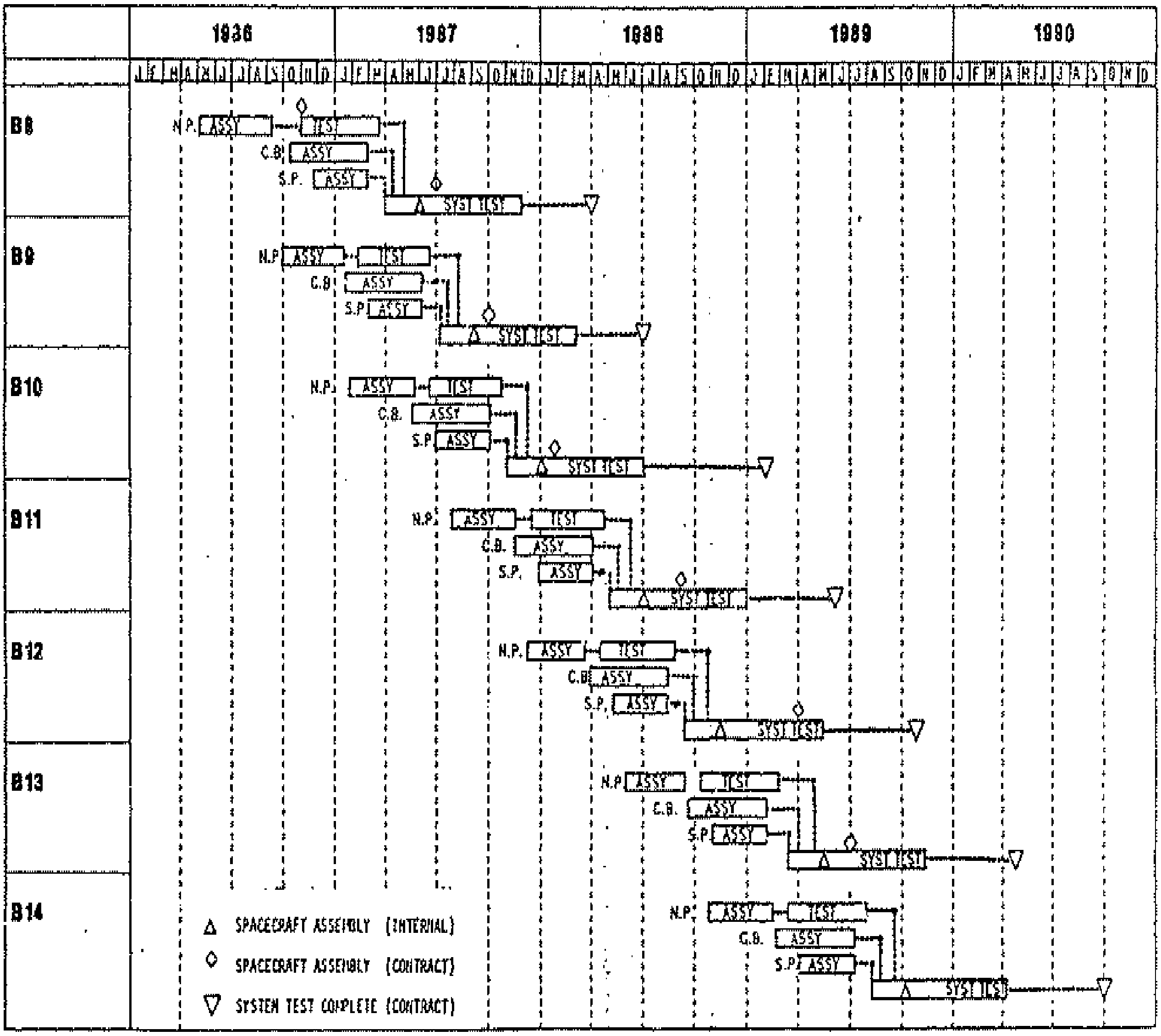


Figure 1-1. DSCS III MYP Production Schedule

1.5 RECOMMENDATIONS FOR FURTHER STUDY

The following three charts show possible future study tasks in three catagories:

- Further analysis of concepts covered in this study
- Additional SHF Enhancement Concepts
- Related desireable satellite improvements

ENHANCEMENT ITEMS RECOMMENDED FOR FURTHER STUDY (SHF COMMUNICATIONS RELATED)

- FURTHER IN-DEPTH ANALYSIS OF CONCEPTS COVERED IN THE PRESENT STUDY:
  - GDA INTERFEROMETER EFFECTS
  - DETAILED GDA PERFORMANCE PREDICTIONS
  - GDA RECEIVE CAPABILITY
  - GDA DIPLEXER ANALYSIS
  - KIDNEY BEAM PERFORMANCE PREDICTIONS AND OPTIMIZATION
- ADDITIONAL CAPABILITIES - NOT COVERED IN PRESENT STUDY:
  - ANALYZE ADDITIONAL WIDEBAND CHANNEL USING OPPOSITE POLARIZATIONS TO DETERMINE:
    - ISOLATION LIMITS
    - POTENTIAL IMPROVEMENTS TO ISOLATION
    - MODULATION SCHEMES TO MITIGATE POOR ISOLATION EFFECTS
    - FREQUENCY BAND LIMITS
    - POSSIBLE SPECIFICATION DEGRADATION DUE TO WIDEBAND CHANNEL

ENHANCEMENT ITEMS RECOMMENDED FOR FURTHER STUDY (SHF COMMUNICATIONS RELATED) (CONTINUED)

- DEFINE AND ANALYZE ADAPTIVE NULLING
  - •• ANALYZE ADAPTIVE NULLING CAPABILITIES WITH ADDITIONAL MBR OUTPUT FOR CH 1 ONLY.
  - •• TRADE OFF NUMBER OF NULLING LOOPS VERSUS CAPABILITY AND HARDWARE COMPLEXITY.
  - •• PROVIDE PRELIMINARY ESTIMATES OF IMPACTS AND PROVIDE PRELIMINARY DESIGN DEFINITION.
- DEFINE, ANALYZE AND TRADE OFF SSA CONFIGURATIONS CAPABLE OF 18 WATTS OF LINEAR POWER.
  - •• DETERMINE RF AND POWER SUPPLY CHARACTERISTICS AND PARTS REQUIREMENTS.
  - •• DETERMINE INPUT POWER, WEIGHT, FOOTPRINT, TELEMETRY AND COMMAND REQUIREMENTS.
  - •• RECOMMEND APPROACH AND COMPARE WITH ULTRALINEAR SSA APPROACH.

SPACE SYSTEMS DIVISION

ENHANCEMENT ITEMS RECOMMENDED FOR FURTHER STUDY (NON SHF COMMUNICATIONS RELATED)

- LOW DATA RATE CROSS LINK FOR TT&C
- POWER SYSTEM UPGRADES TO PROVIDE 45-50% INCREASE IN CAPABILITY
- PAS
- YAW CONTROL UPGRADES
- SYSTEM INTEGRATION STUDIES FOR ALL ENHANCEMENTS

SECTION 2

SPECIFIC ENHANCEMENTS

SECTION 2

SPECIFIC ENHANCEMENTS

2.1 OPTION A VEHICLE INTEGRATION OF AN ADDITIONAL GIMBALLED DISH ANTENNA (GDA)

2.1.1 SELECTED APPROACH

A trade-off of positions to mount a second GDA has shown that the placement of the two antennas at the bottom plane of the spacecraft is the best location (See Figure 2.1-1, -2 and -3). The advantage is that like installations can be achieved. Also the two GDAs can be stowed in the space between the stacked spacecraft payload assembly. The structural tie for each assembly will consist of fabricated structure attached to the base of the center body structure. Mounted to the structure, a rotary actuator would swing the GDA from its stowed position to its active location. The antenna mounted to its yoke would be driven in its second axis by an actuator mounted to one side of the yoke A fixed feed horn will be structurally secured to the side of the center body structure.

The actuators used for this GDA would consist of adaptations of the present GDA design. These new actuators would require new gear configurations to account for the increased swing of the boom actuator and probably slight changes in the yoke actuator.

It is anticipated that a launch lock will be required to secure the GDA during launch. This launch lock design will be similar in function to the present GDA launch lock. The details of the design will involve changes to the structural ties to accommodate this new configuration.

Thermal control of the GDA will consist of multi-layer insulation blankets similar to the insulation used on the present GDA. The insulation will enclose the entire structure, actuators and antenna. Heaters and thermostats

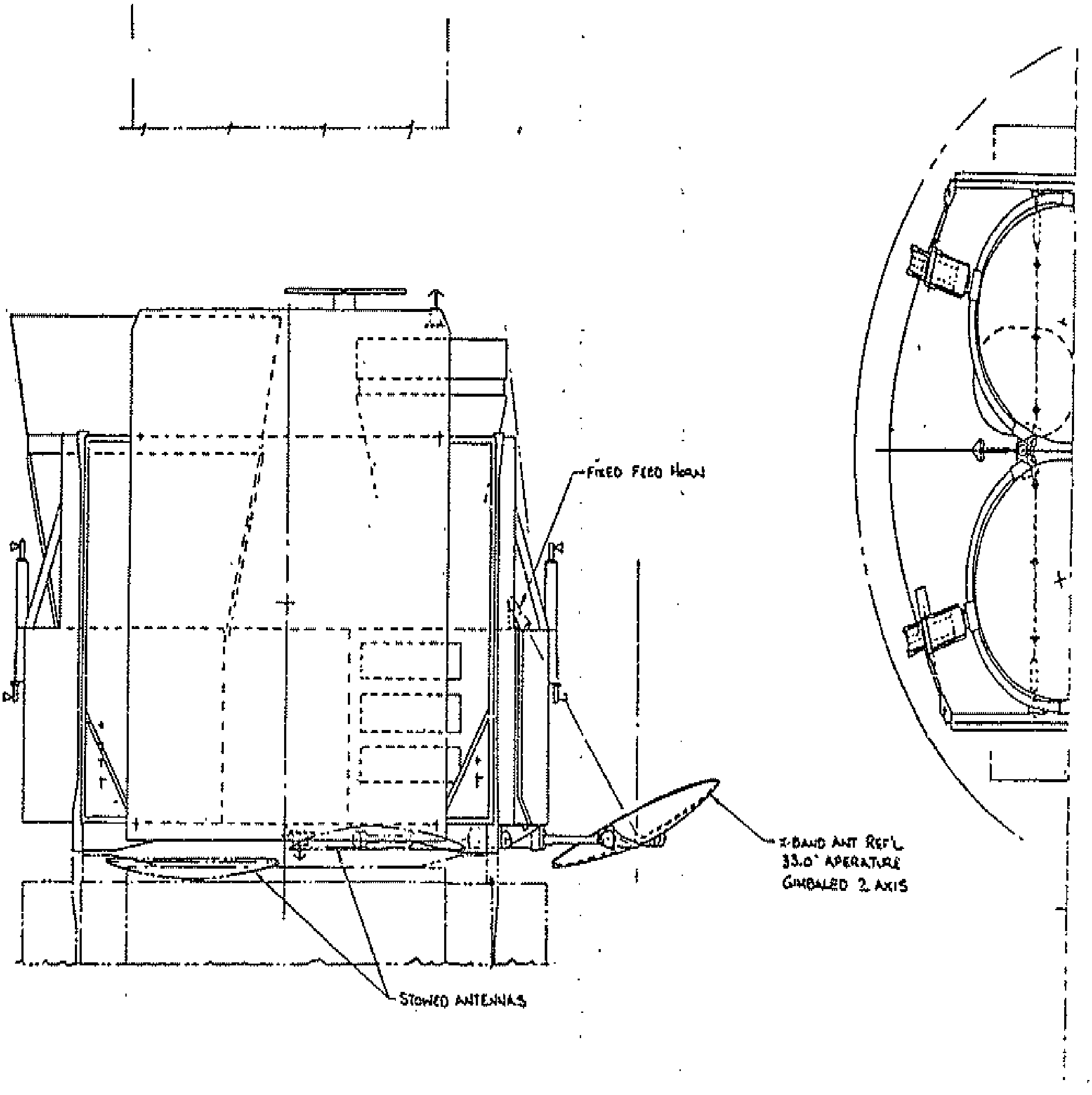


Figure 2.1-1. Twin Gimballed Dish Antenna Installation

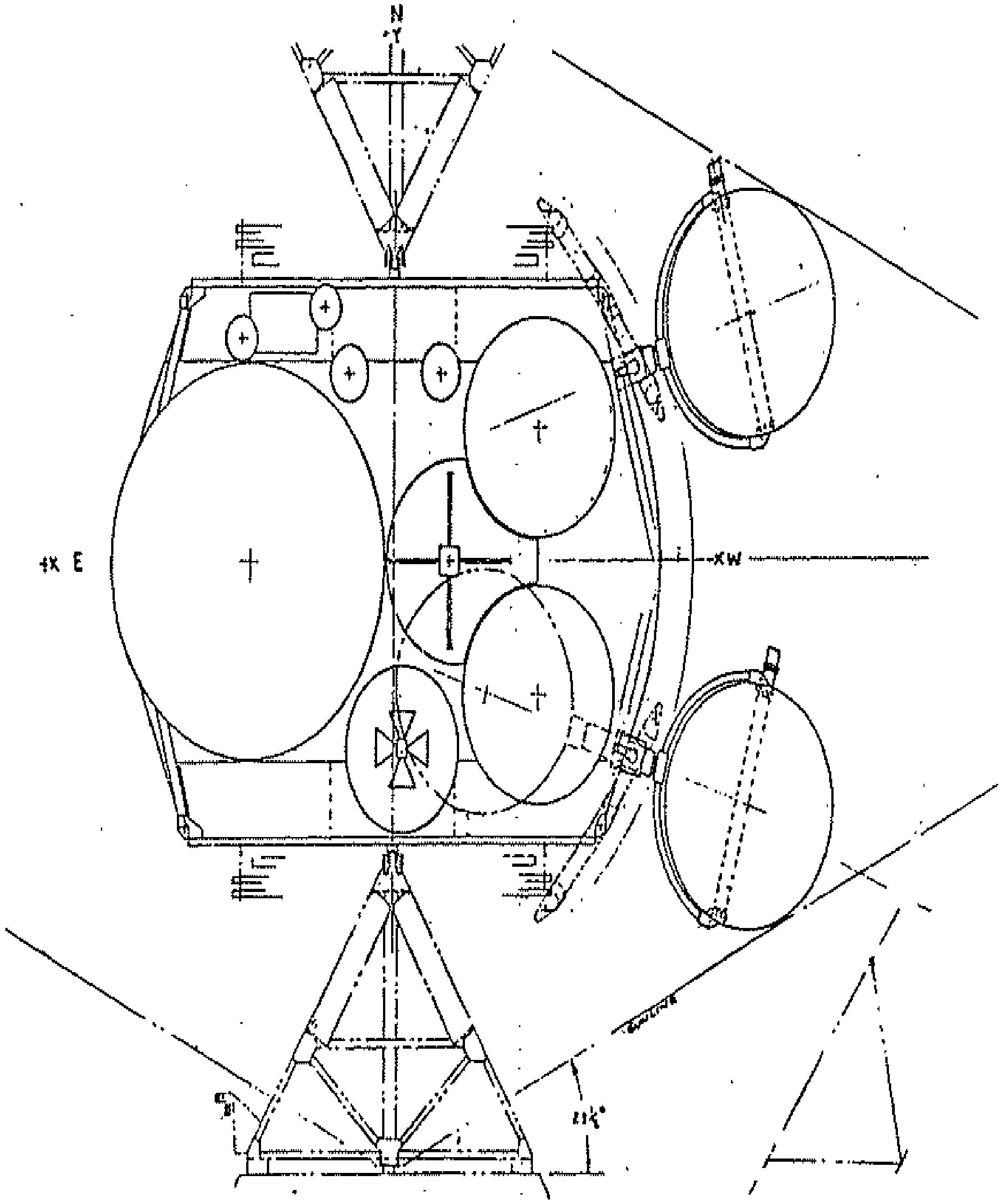


Figure 2.1-2. Twin Gimballed Dish Antenna Assemblies Deployed

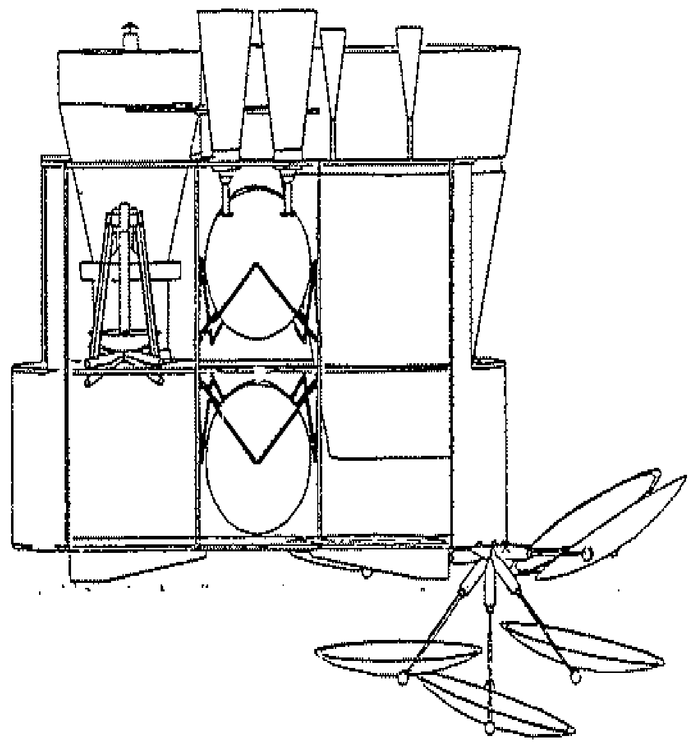


Figure 2.1-3. Deployment Sequence for GDA

will be provided to maintain proper temperature control. Additional heater power will be expended for the 2nd GDA. A service loop will be provided to pass the harness across the rotary joint of the boom actuator.

This new GDA configuration will require a complete qualification program using protoflight dynamic testing at the first flight article. It is anticipated that Antenna testing will be required to prove that the insulated GDA will operate within space Antenna performance parameters even though the feed horn is not in the same insulation cocoon.

The build-up and testing of the GDA will be handled in a similar fashion to the present GDA. That is, the units will be completely tested as a separate sub-assembly and installed on the spacecraft at an appropriate time in the spacecraft assembly cycle. However, there will have to be an auxiliary feed horn holder that will position the feed horn relative to the Antenna for test

purposes. The prime feed horn will be used in each acceptance/protoflight test of the spacecraft.

The advantage of this design is that the GDAs can be added to spacecraft without major structural redesign of the spacecraft. This design with its fixed feed horn eliminates the need for an RF rotary joint. The basic elements of the present GDA design can be adapted to this new configuration. However, this is a new GDA and will require Antenna development tests, Actuator design tests and sub-assembly environmental tests.

The weight added to the spacecraft is as follows:

Deletion of Present GDA	26.2 lbs
Additions of two new GDAs	24.6 x 2 = 49.2 lbs
Total Vehicle	23.0 lbs

Plume Impingement From Propulsion S/S on GDA

Note that in Figure 2.1-1 that the west propulsion control nozzles are above the GDA antenna. The nozzle exhaust gas envelope would require study to insure that no thrust vector would be imparted to the vehicle because of impingement of the exhaust plume on the GDA Antenna.

Shadowing of the Sun Sensor by the Second GDA Antenna

A study is also required to insure that there is no shadowing of the sun sensor located on the Solar Array Assembly by the Second GDA Antenna. Spacecraft control could be effected by the problem of shadowing.

2.1.2 ALTERNATE APPROACH

Along the path of configuration development, two other ways of achieving dual GDAs were studied.

The first alternate configuration positioned the second GDA in a stowed position between the 61 MBA and the 19 MBAs. See Figure 2.1-4. The GDA antenna would be attached to a rotating boom pivoted at the top edge of the south panel. This boom would deploy in orbit to move the second GDA to an outboard position of the first GDA (See Figure 2.1-4).

In order to provide room for the stowing of this new GDA, the UHF transmit Antenna would have to be moved. A new location and a substitution of a deployable Yagi Antenna on the top of the South Panel Bookcase Assembly will be required. The Upper Meteoroid shield would likewise require redesigning to accommodate the recessing of the stowed GDA into the center body.

An additional launch lock and actuator would be required to secure the GDA during launch and to rotate it into position when orbit was achieved.

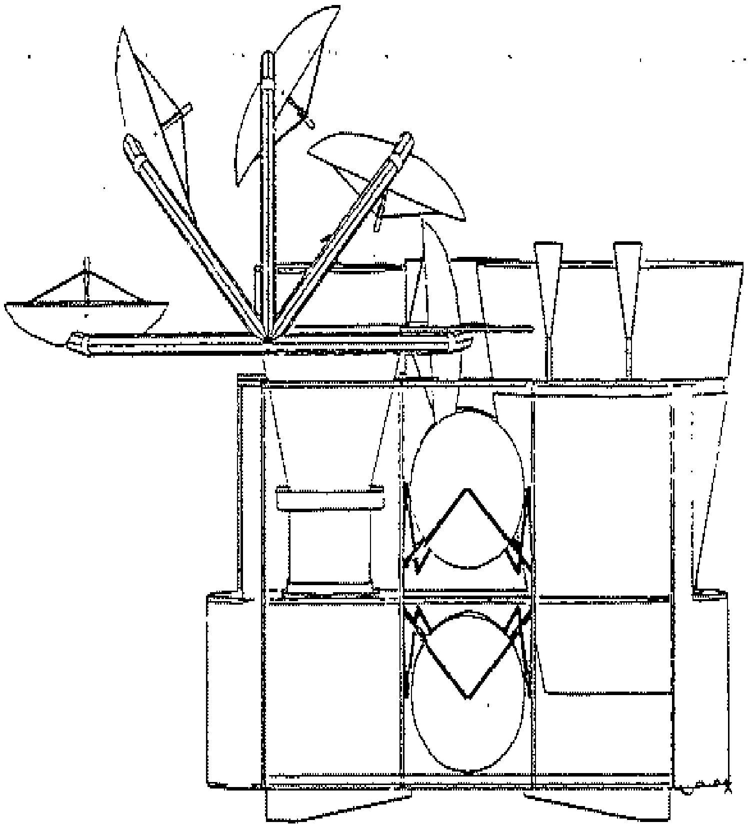


Figure 2.1-4. First Alternate GDA Installation

This GDA adaption has the advantage of using exactly the same GDA Antenna and drive system as the present design. New structural ties would be required to secure the Antenna to the deployment boom however, this is straight-forward structural design.

The second configuration involved leaving one GDA where it is presently located and placing the second GDA in the cavity under the 19 MBAs (see Figures 2.1-5 through 2.1-9). There is room in this compartment to install the second GDA, however, a whole new structural design would be required to support the present 19 MBAs. As designed, there are eight graphite -epoxy struts in this compartment carrying the MBA loads to proper structural mainframes.

A second problem is the fact that some kind of a thermal door and micro-meteoroid shield would be required to close over the cavity needed to allow room for the new GDA to deploy into its proper operating position.

In the deployment, the boom would have to be a telescoping device. The wave guide attached to the telescoping boom would require a series of rotary RF Joints (build like a carpenter's collapsing ruler) to allow the boom to move out to its operating position. Alternately, a special choked non-contacting waveguide interface could be designed to align itself upon erection.

On the positive side, the basic design of the present GDA could be retained eliminating this Antenna development.

However, considering the extent of the structural redesign and requalification of the center body structure, the design of a thermal door and the boom design, this design was rejected.

The third dual GDA design considered removed the MIX 19 MBA to allow room for a second GDA (see Figures 2.1-10 through 2.1-12). This second GDA would be identical to the present GDA. Adjustments to the truss assembly would be

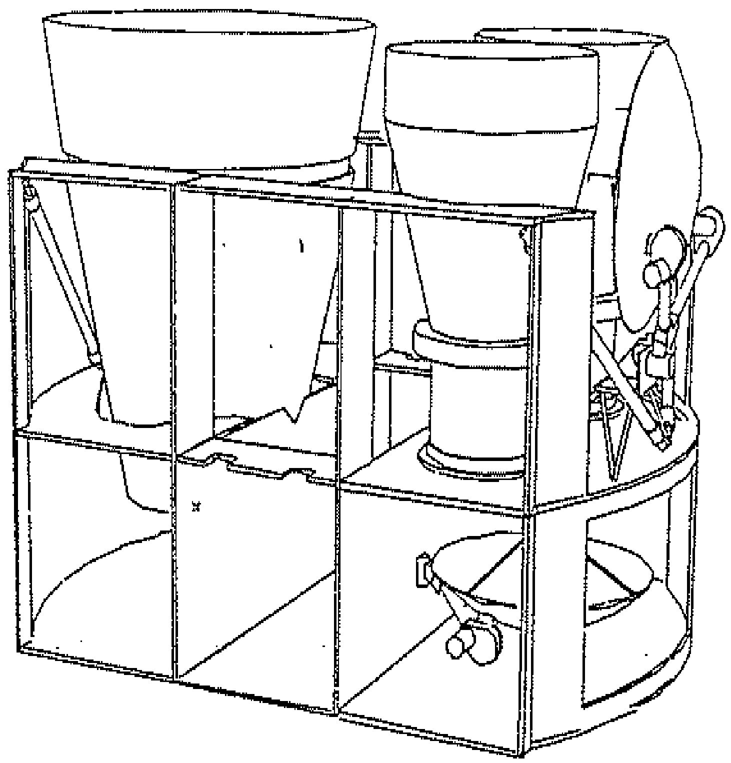


Figure 2.1-5. 2nd Alternate GDA Installation (Stowed)

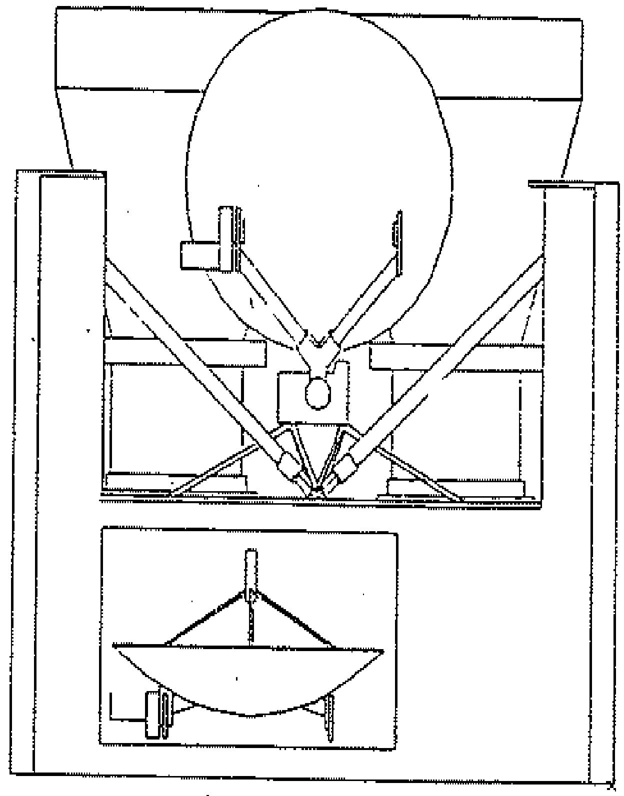


Figure 2.1-6. End View of 2nd Alternate in Stowed Position

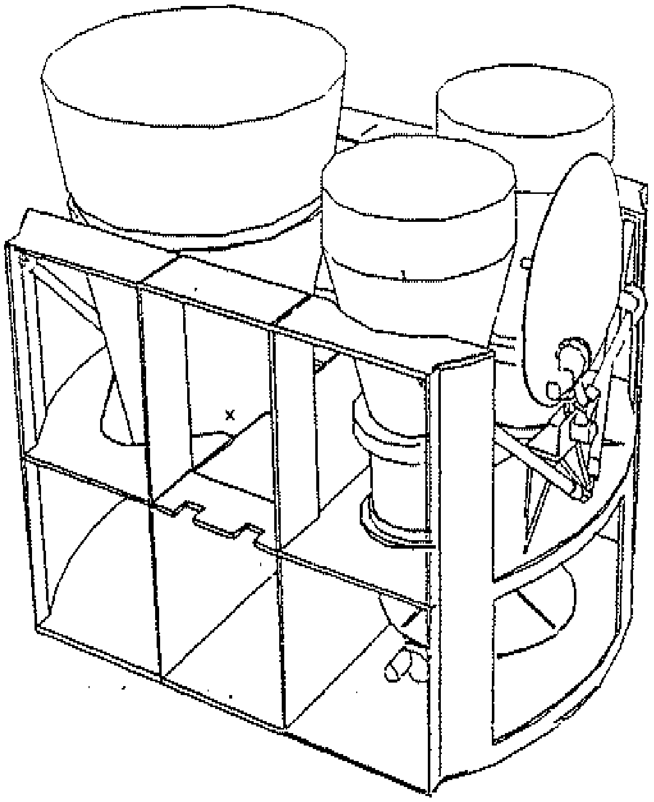


Figure 2.1-7. Three-Quarter View of 2nd Alternate GDA

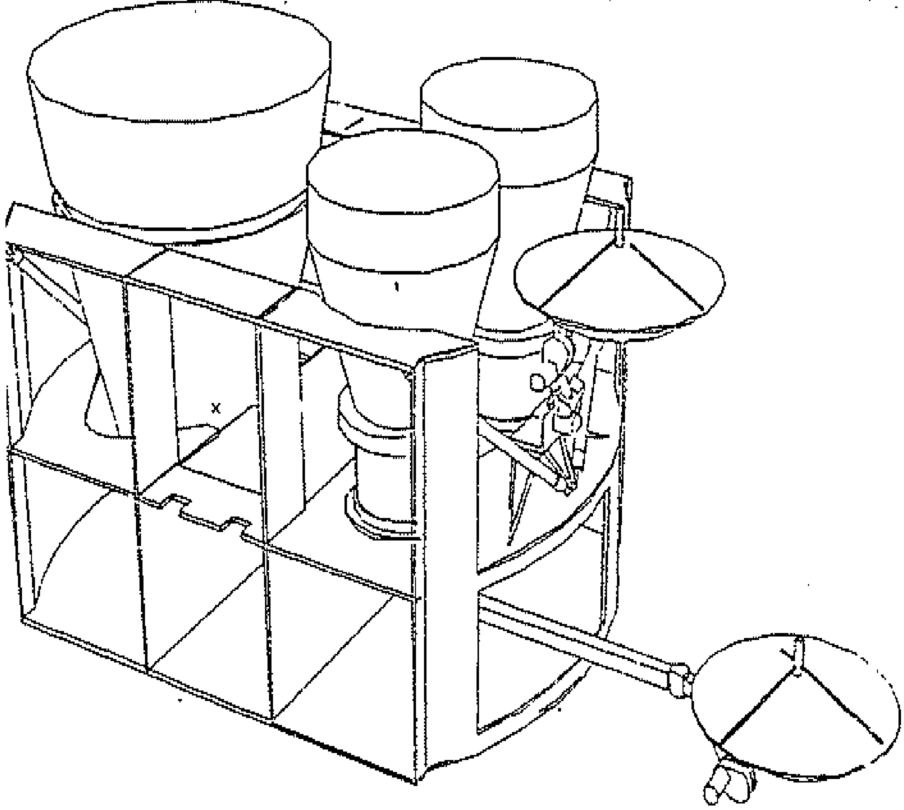


Figure 2.1-8. 2nd Alternate GDA in Deployed Position

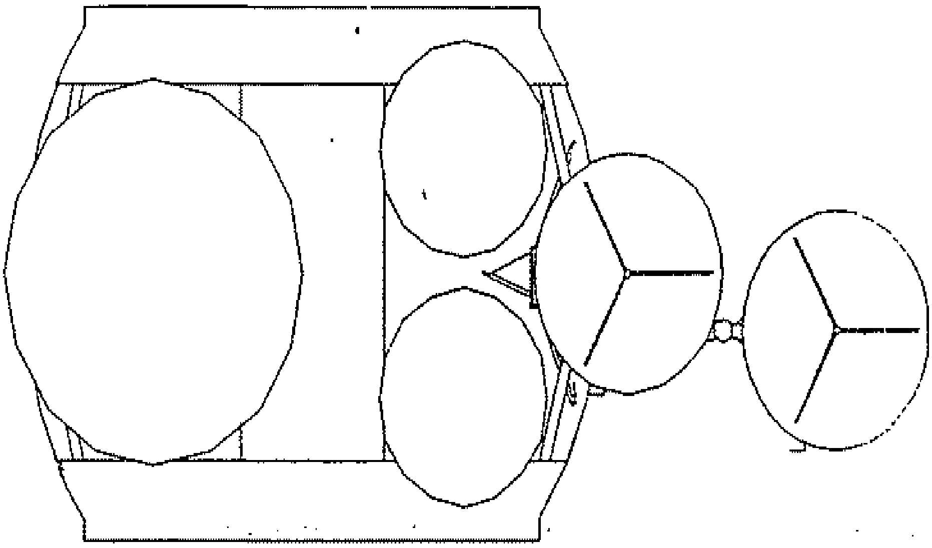


Figure 2.1-9. Top View of 2nd Alternate GDA (Deployed)

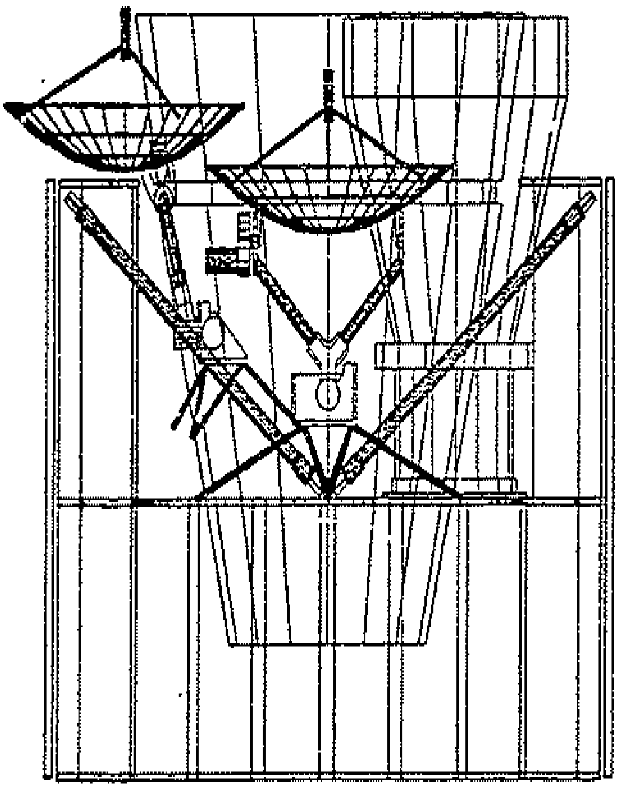


Figure 2.1-10. 3rd Alternate GDA Design (Deployed)

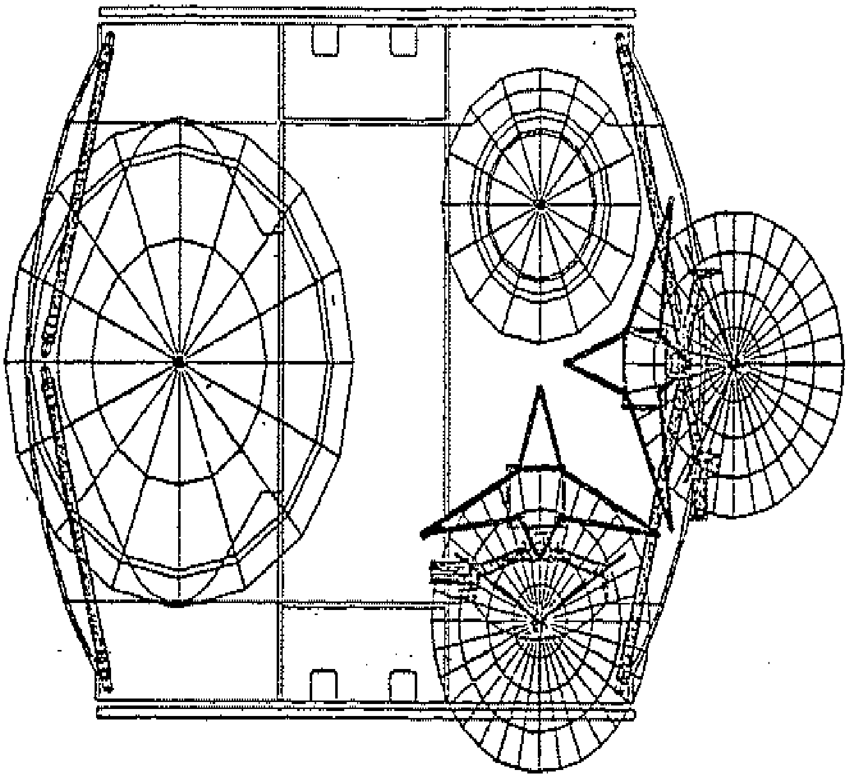


Figure 2.1-11. Top View of 3rd Alternate GDA Design (Deployed)

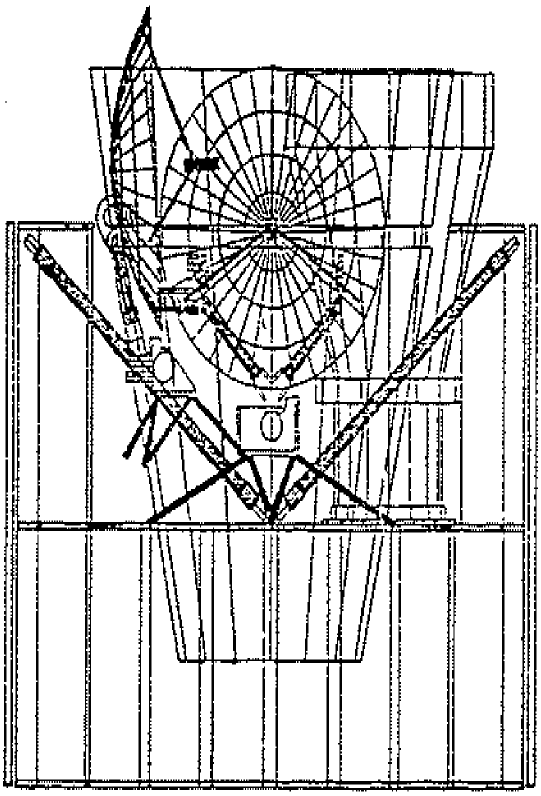


Figure 2.1-12. 3rd Alternate GDA Design in Stowed Position

required so that the GDA could be mounted above the lip of the south panel. This is required so that the GDA can rotate through its required pattern. The structural ties of the truss can be secured into the center body mainframes.

This design has the advantage of using present design configurations adapted to a new location. Thus no antenna development is required. However, the loss of the 19 MBA represents an operational capability restriction. Thus this approach was not selected for costing through it remains a viable candidate under option.

Of the three alternate approaches studied the first alternate has a great deal of merit. Even though this report favors the first approach discussed, the first alternate has merit and will be carried forward into the preliminary design stage.

2.1.3 MODIFICATION KITTING OF THE SECOND GDA (See Figure 2.1-13)

It is the intention of each of the options under consideration to adapt the design so that a modification kit can be employed to install any of the new antennas such as the second GDA. Each design has looked at what modifications can be made to attach the Antenna at an optimum time in either the build-up phase of spacecraft construction or even when the S/C is assembled.

In the case of the second GDA, the GDA design and manufacture can be handled in parallel to the normal spacecraft part manufacture and assembly. The structural ties to the vehicle center body would be designed to use existing hard points. Modifications to the electronic "black boxes" would consist of using spare slots in existing components to add the required control and heater power requirements. These electrical changes would form a part of the modification kits.

Given a clever execution of this concept, these modification kits can be inserted into the Multi-year Procurement at an optimum time to enhance SHF antenna performance at any vehicle agreeable to GE and SD-HQ.

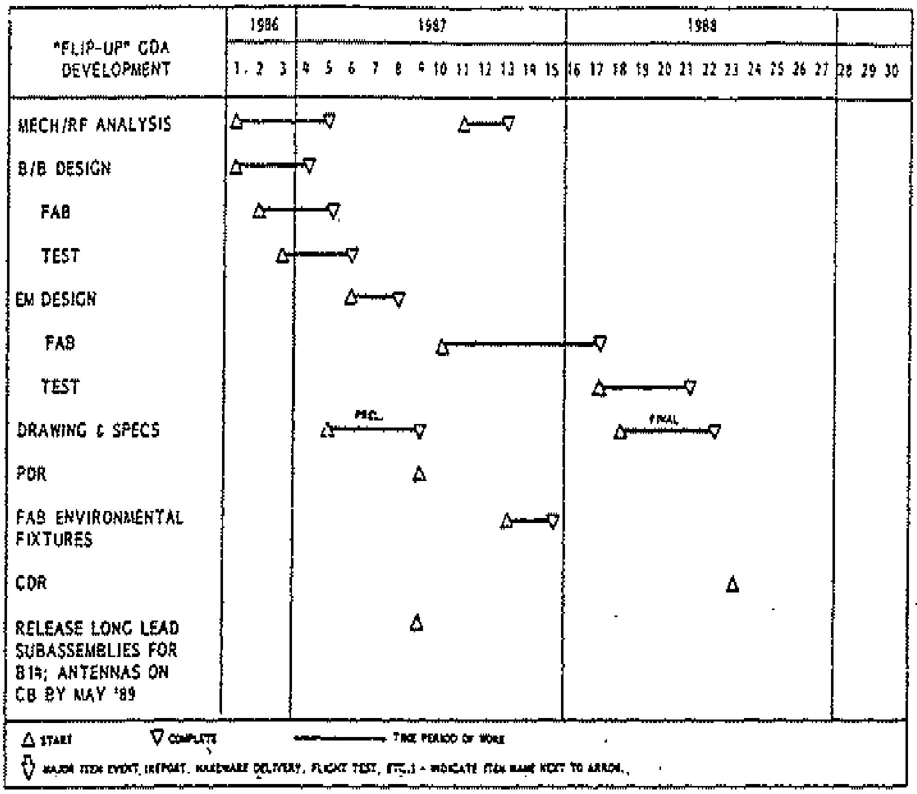


Figure 2.1-13. Additional GDA Development Schedule

2.1.4 NORTH PANEL ASSEMBLY MODIFICATIONS

The second GDA will require minor modifications to the North Panel assembly. This change involves the removal of the C15-2T Antenna Select Switch and the addition of a variable Power Combiner (VPC) along with an FL8-2 filter. Along with these component changes, waveguide runs will require alterations. Any changes to the North Panel will require detail layout work along with a mockup update to achieve an assembly that can be fabricated. The changes look manageable.

2.1.5 STRUCTURAL ANALYSIS TASKS FOR SHF ENHANCEMENT

For all the options considered, it is anticipated that an additional Load Cycle Analysis would be required. Modal changes to the spacecraft would be handled by analysis rather than an additional Modal Survey Testing.

2.2 TRANSMIT EARTH COVERAGE HORN IMPROVEMENT

2.2.1 DESCRIPTION OF SELECTED APPROACHES

Earth coverage gain improvements result from pattern shaping by aperture control. Since the edge of earth is located further away from a geosynchronous spacecraft than is the point on the earth directly below the spacecraft, users at the edge of earth (EOE) experience a larger path loss due to the 1/R**2 power law. In order to provide a uniform power density at all points on the surface of the earth the optimum pattern should have higher gain at the edge of earth aspect angles than at boresight. This optimum pattern should also drop to zero just beyond the edge of earth. An infinite aperture would be required to concentrate all the radiated power in the solid angle subtended by the earth. A mini-max optimization was applied to finite apertures to approximate this ideal case. The optimization minimizes the maximum deviation from the ideal for the available degrees of freedom of a finite aperture. The results for two apertures sizes are given in Figure 2.2-1. Also shown in the current DSCS ECH and ideal pattern for comparison.

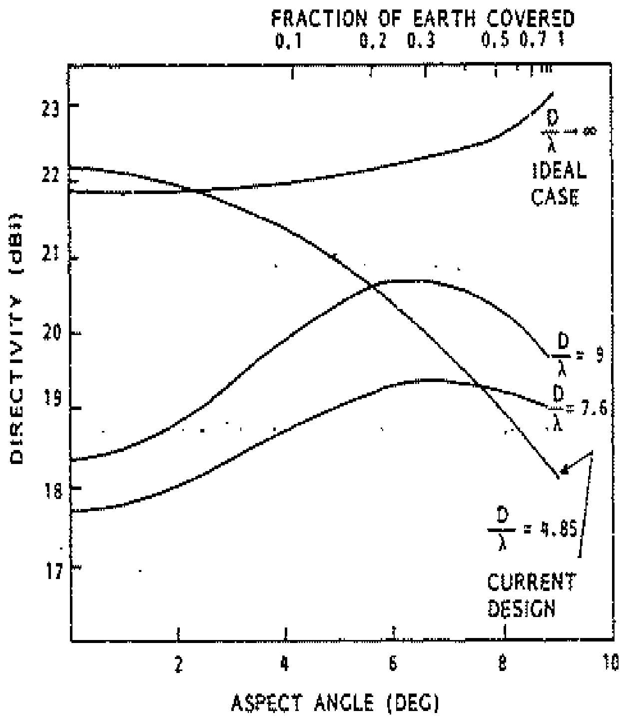
In comparison of the current design and the 7.6 wavelength aperture, it may be argued that an increase in gain over aspect angles from 7.5 degrees to 8.8 degrees is obtained only as a result of a loss in gain over angles less than 7.5. This seems at first to be a poor tradeoff until the percent of earth improved is considered. The gain at the higher aspect angles is most important since for these aspect angles a much larger surface area is covered for a small change in angle. Thus an improvement over 59% of the earth is obtained for gain improvement from 7.5 to 8.8 degrees. (See percent earth coverage axis Figure 2.2-1)

Since aperture is the price to be paid for improved earth coverage the question becomes what mechanical penalties must be paid to accommodate aperture size increase. This naturally breaks the problem into two regimes: what is the maximum gain increase available for those solutions which will fit on the current spacecraft without an MBA removal, and what is the mechanical

IMPROVEMENT:

By increasing the gain at the edge of earth to compensate for increased path loss, a limited aperture antenna can deliver a nearly constant flux density at the Earth's surface

ANTENNA PATTERNS AS A FUNCTION OF APERTURE



EXPECTED PERFORMANCE:

CONFIGURATION	DIAMETER/ WAVELENGTH	EOE IMPROVEMENT	ANGULAR CROSSOVER	FRACTION OF EARTH WITH IMPROVED GAIN
DSCS ECH	4.85	0 dB	-	-
MAX APERTURE ON CURRENT CONFIG.	7.6	0.85 dB	7.5 deg	59%
THEORETICAL MAX IMPROVEMENT	Infinite	4.9 dB	2.3 deg	95%

Figure 2.2-1. Earth Coverage Horn Improvement

penalty/gain increase tradeoff for those designs which must be coupled with an MBA removal. There are two approaches selected for improved earth coverage: a minimum impact design providing a gain increase over 59% of earth coverage and a major impact design improving coverage over 80% of earth.

The largest aperture which can be accommodated on the current spacecraft is 12 inches in diameter or 7.6 wavelengths. This size aperture can be realized with multimode feed horn techniques. A sketch of the multimode feedhorn and a DSCS ECH are given in Figure 2.2-2. The impact of the replacement of two transmit ECH's with the modified design is minimal. The locations of the meteoroid shield penetrations would be modified as well as the length and placement of the waveguide runs. The horn itself would utilize the same orthomode coupler and polarizer as the current design and the prime units would be electroformed by a specialty vendor.

Any aperture over the 12 inch diameter requires the improved ECH option to be coupled with the removal of the MBA. It is difficult to realize large apertures (10 wavelengths or larger) using feed horn techniques. The lengths of the feeds become extremely long and impractical. The aperture distribution required to give the earth coverage far field patterns of interest have most of their energy (98%) near the center of the aperture and a small amount (2%) with 180 degree phase shift at the outer edge of the aperture. This suggests a coaxial design with a small amount of coupling to the outer ring section. Proper use of the cutoff properties of the various coaxial/waveguide sections provide the 180 degree phasing. (See Figure 2.2-3.)

2.2.2 PERFORMANCE

The 12 inch aperture design improves the EOE coverage by approximately 0.85 dB and maintains the current gain specification of 17 dBi over all aspect angles. A pattern from the circular aperture using the first three waveguide modes is given in Figure 2.2-4. The axial ratio of the three mode feed

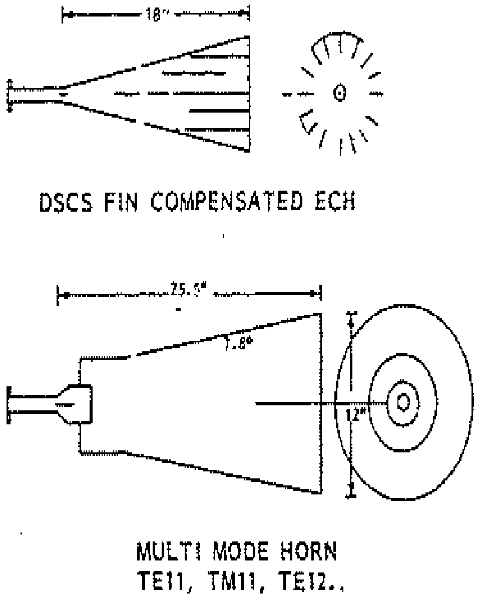


Figure 2.2-2. Earth Coverage Horn Size Comparison

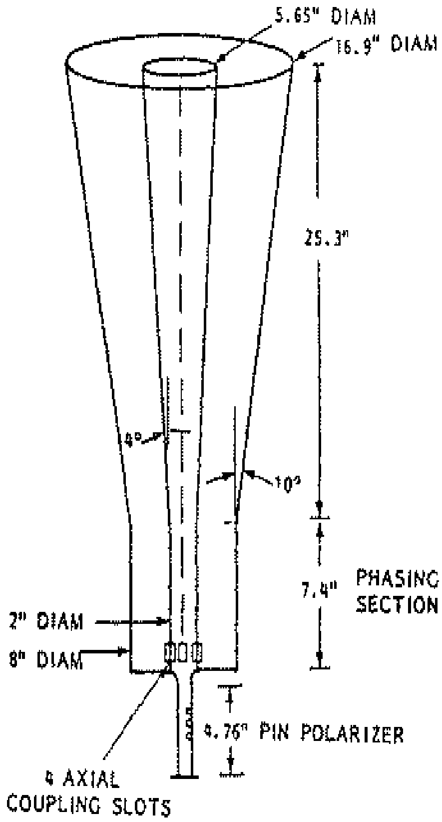


Figure 2.2-3. Coaxial Feed ECH

pattern meets the 1 dB axial ratio specification but the effect of the imperfect polarizer was not considered. The axial ratio of the antenna can be improved by the addition of a fourth mode (see Figure 2.2-5) but the resulting bandwidth may be limited.

The performance of the coaxial feed was approximated by a hexagonal array of equal aperture area where the outer ring elements were excited out of phase from the center element. The non-optimized result was an increase in EOE gain of 1.5 dB. (See Figure 2.2-6)

2.2.3 BENEFITS

The benefit of the new design is an increase in signal strength for EOE users.

2.2.4 IMPACTS

The 12 inch design has a weight increase of 4 lbs/horn and a 7.5 inch overall increase in length to be accommodated by the removal of waveguide. The aperture height fits inside the IUS envelope.

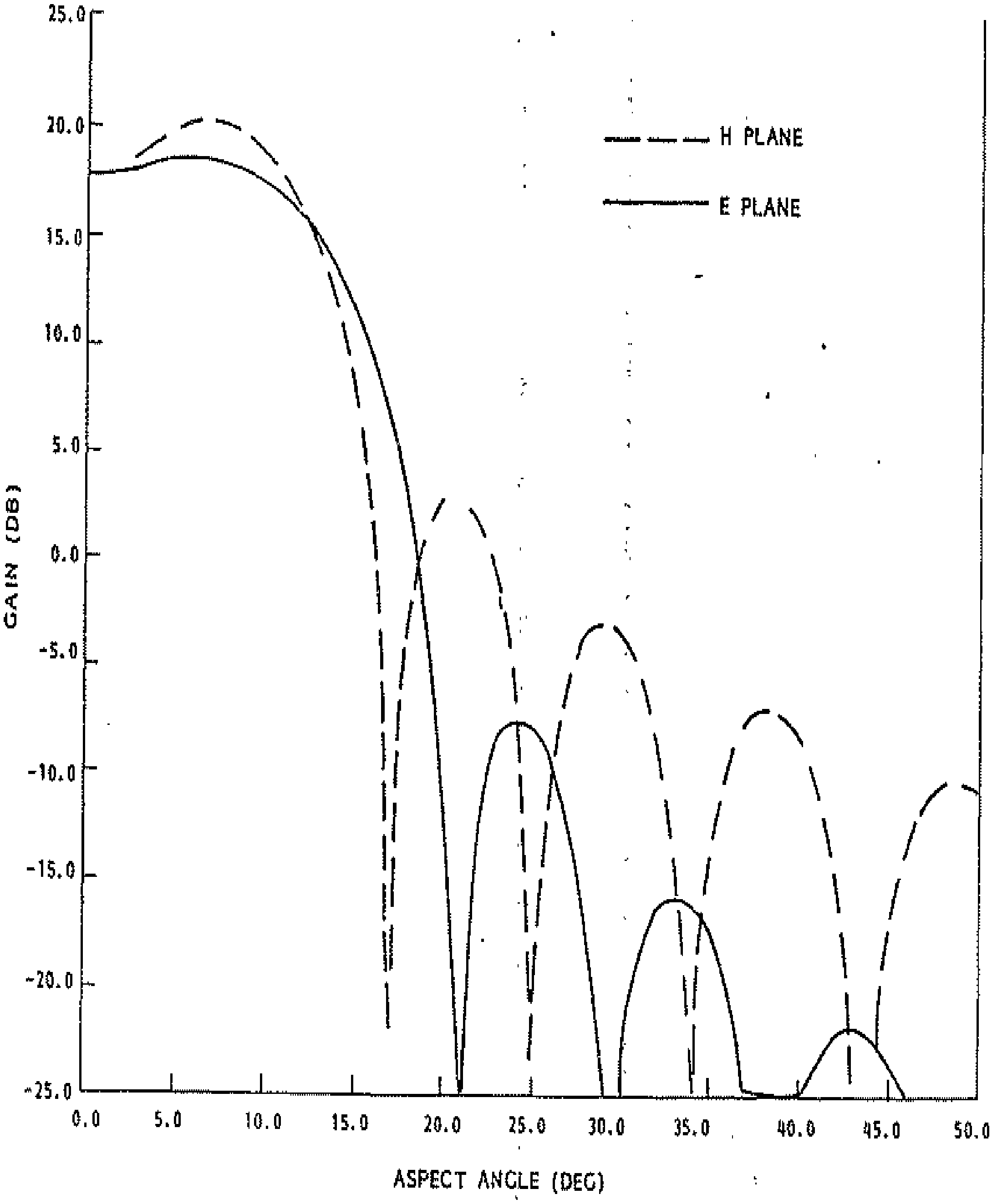


Figure 2.2-4. E and H Plane Patterns of Three Mode Horn D/WL=7.6

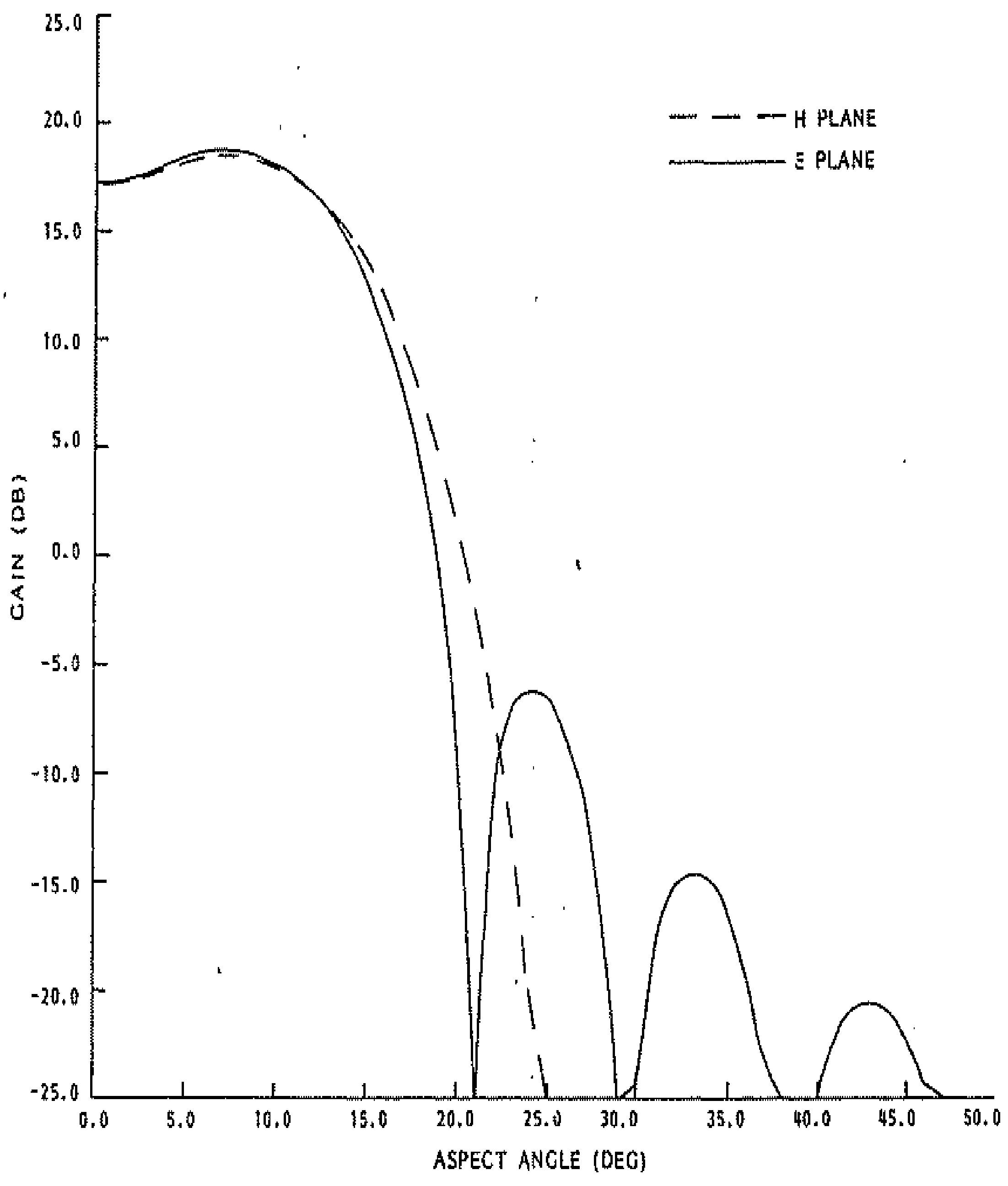


Figure 2.2-5. E and H Plane Four Mode Horn D/WL=7.6

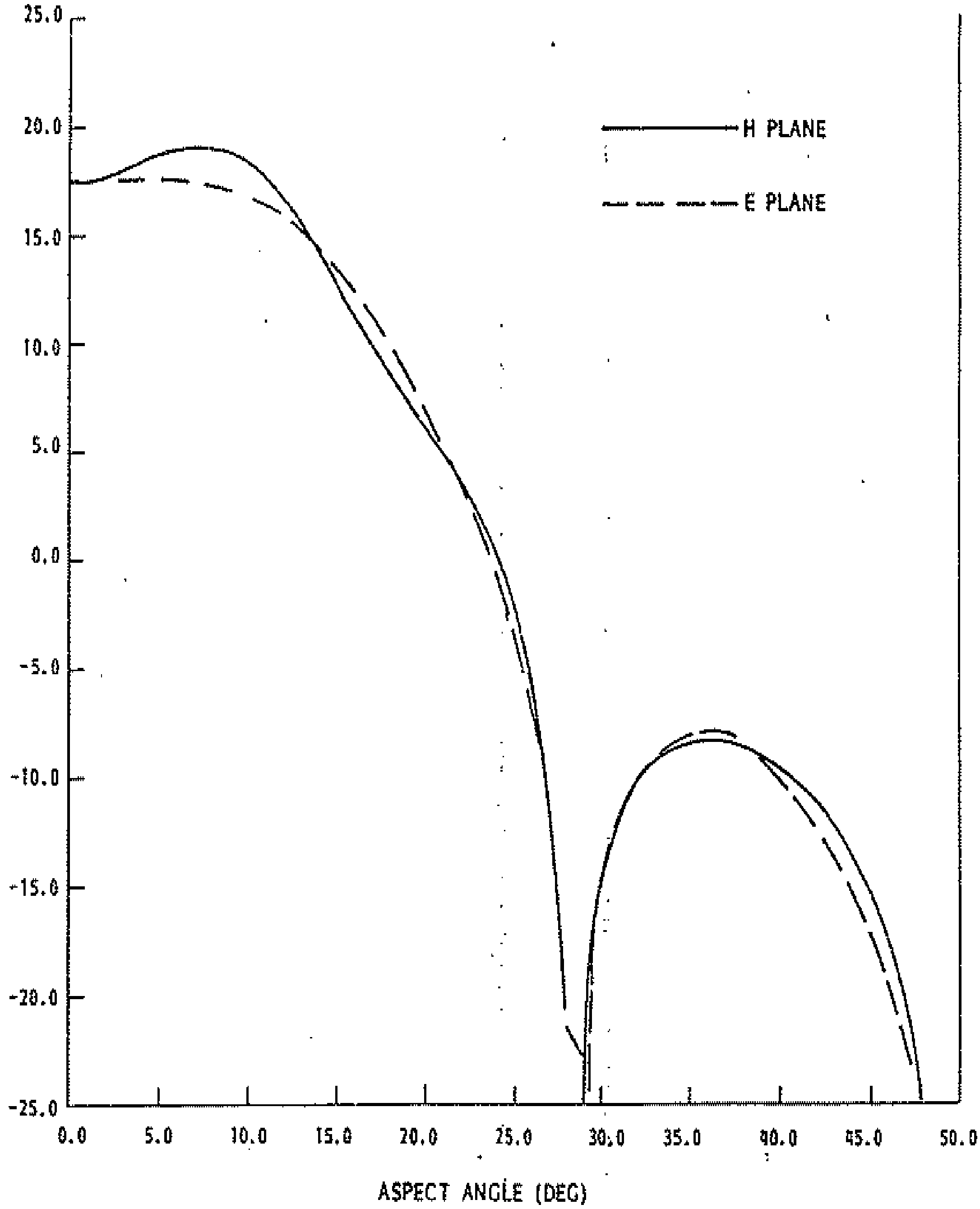


Figure 2.2-6. E and H Patterns Non Optimum Hex

The 9 wavelength design has a relatively large impact on the spacecraft requiring the removal of an MBA, redesign of waveguide runs, meteoroid shield and thermal protection.

2.2.5 RISKS

The 12 inch multimode horn is a low risk improvement. An extensive data base on dual mode horns and computer models including analysis, data reduction, and aperture mode fitting programs are in place.

The larger aperture coaxial feed has a higher risk in the development phase due to the lack of in-place models for the design of the coaxial sections. Careful control of spurious modes in the horn must be used, possibly requiring a mode suppression section, increasing the overall feed length.

2.2.6 RATIONALE FOR SELECTED APPROACH

Other realizations of the 12" design considered were corrugated horns and coaxial feeds but either option represented an increase in weight and manufacturing complexity.

The larger aperture realizations considered were a stepped dish approach and a hexagonal array. The dish solution suffers from blockage, spillover and waveguide losses as well as diffraction effects of the steps required to produce the 180 degree phase change in the aperture distribution necessary for the shaped pattern. The hexagonal array requires a beamforming network necessitating an increased aperture size to offset the ohmic losses.

2.2.7 VEHICLE INTEGRATION

All configurations considered were installed in a position where the present EC horns are located. The layout work, accomplished using GE's GEOMOD computer program, showed that the 12" diameter E.C. Horns would fit without major structural changes. See Figure 2.2-7, -8, -9 for the Multimode Horn and the Hybrid Mode Corrugated Horn. Each configuration will require changes to the Meteoroid Shield and a new structural tie to the center body structure.

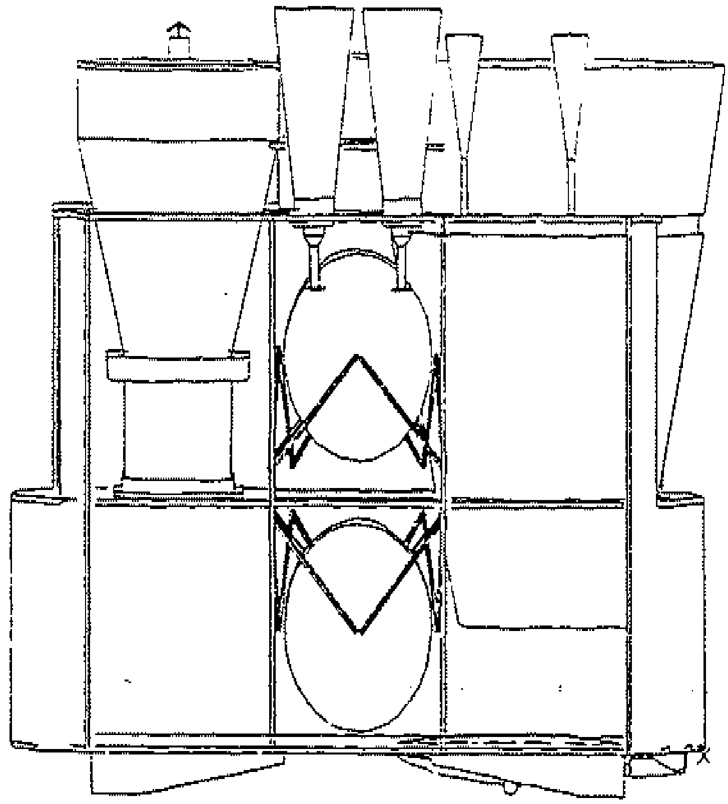


Figure 2.2-7. Side View of DSCS Spacecraft with Multimode Horns

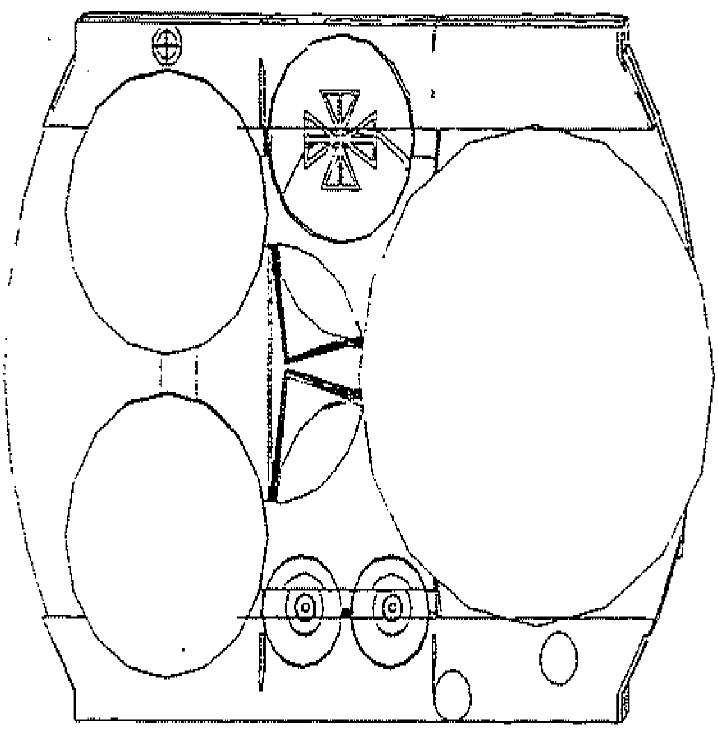


Figure 2.2-8. Top View of DSCS Spacecraft with Multimode Horns

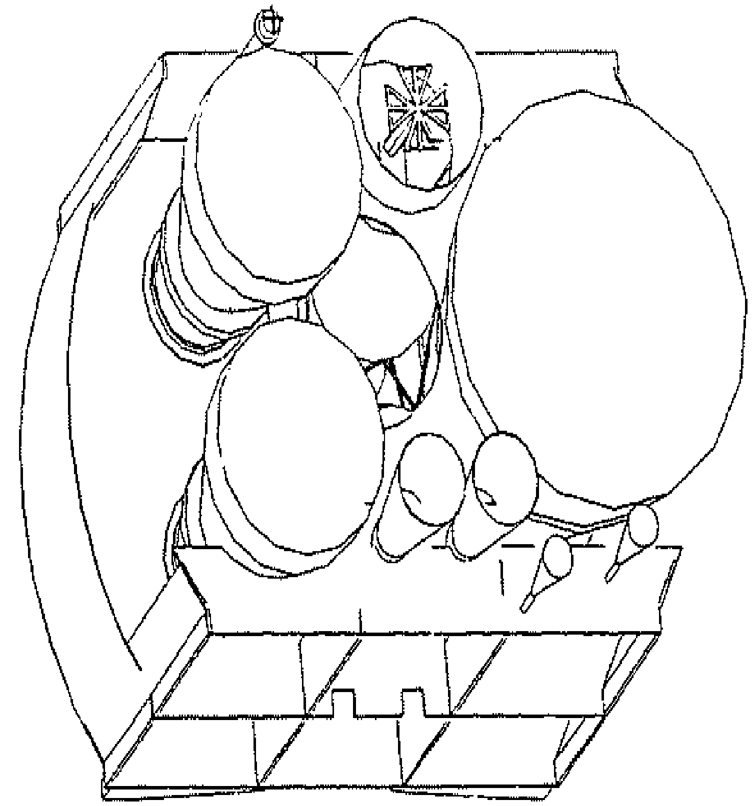


Figure 2.2-9. 3/4 View of DSCS Spacecraft with Multimode Horns

The waveguide connected to these two candidate E.C. Horns will require adjusting and new supporting brackets. This is considered a minor change. These changes would fit well with the modification kit scheme explained earlier.

See Figure 2.2-10, -11 and -12 for vehicle installation assemblies of the Coaxial Ring Array E.C. Horn. This candidate can also fit within the physical constraints of the area available for the E.C. Horns with similar changes delineated in the above paragraph.

However 15" diameter approach and the 7 cluster E.C. Horn approach present a problem. In both cases the E.C. Horn is too big to fit more than one horn. (See Figures 2.2-13 through -18)

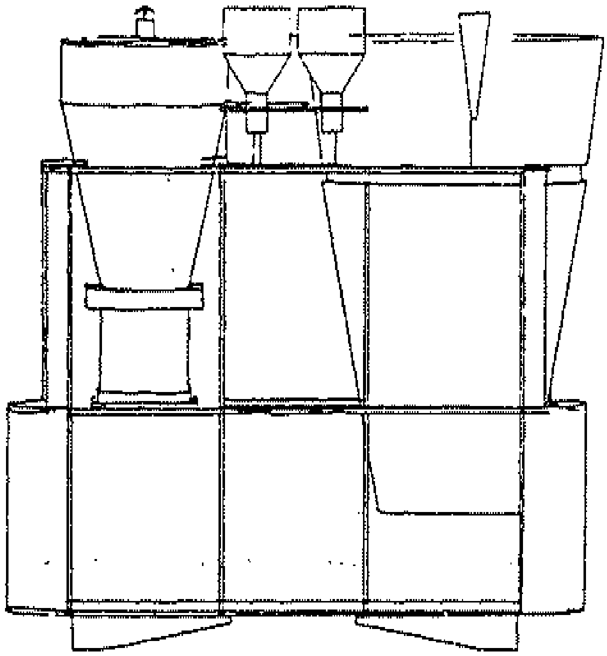


Figure 2.2-10. Side View of DSCS Spacecraft with Coaxial Ring Array E.C. Horn

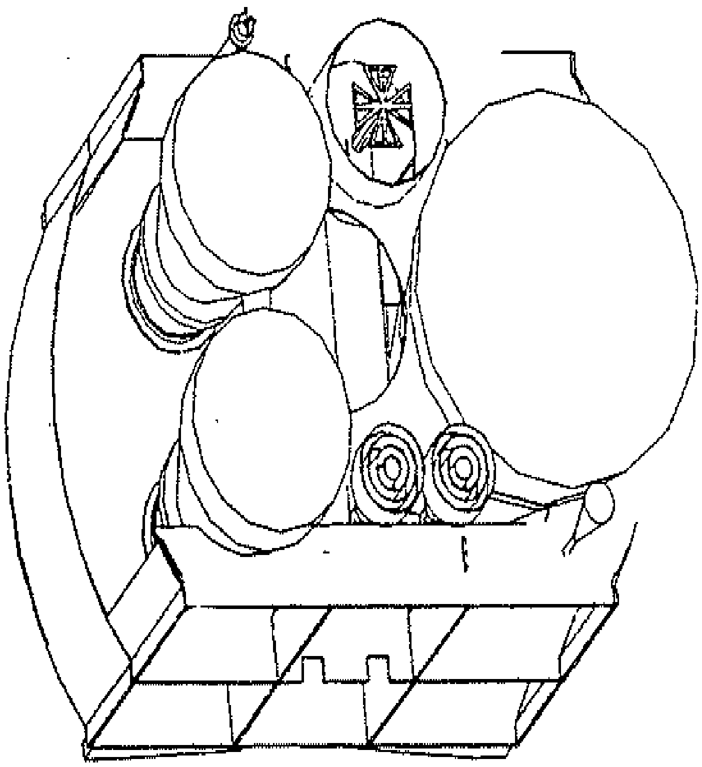


Figure 2.2-11. 3/4 View of DSCS Spacecraft with Coaxial Ring Array E.C. Horn

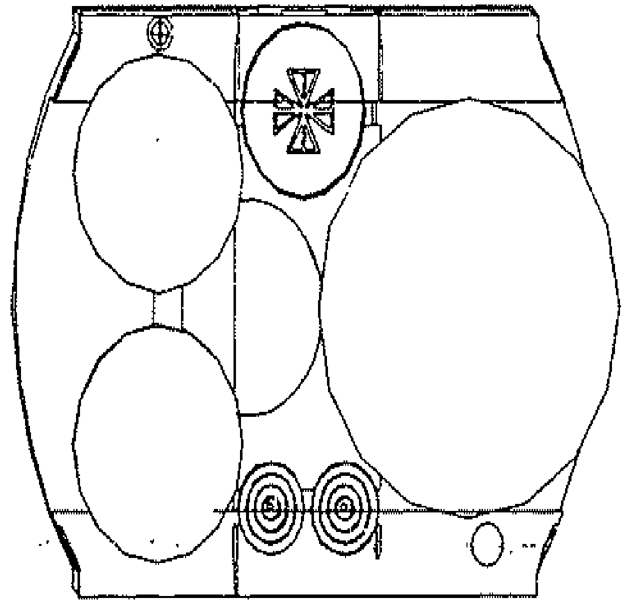


Figure 2.2-12. Top View of DSCS Spacecraft with Coaxial Array E.C. Horn

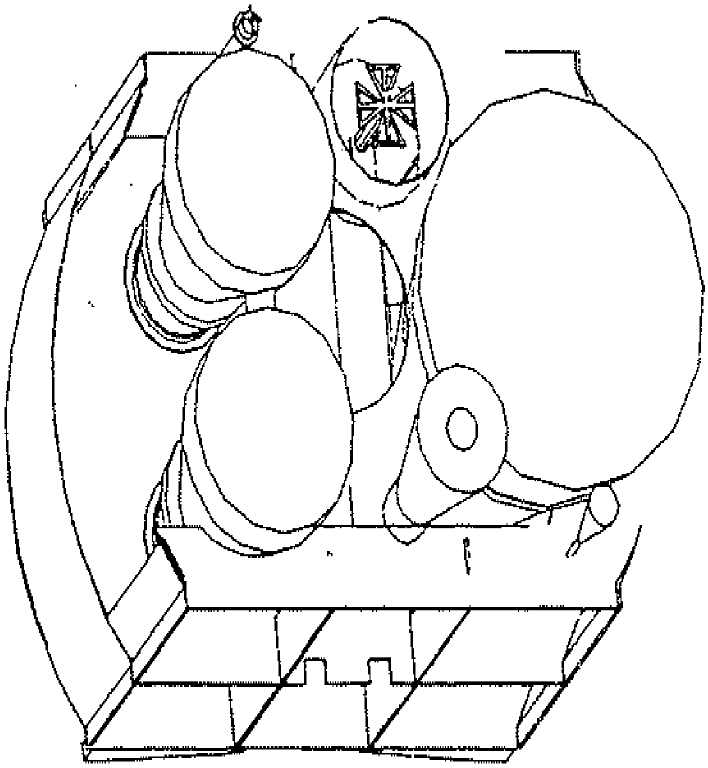


Figure 2.2-13. 3/4 View of DSCS Spacecraft with 15" DIA E.C. Horn

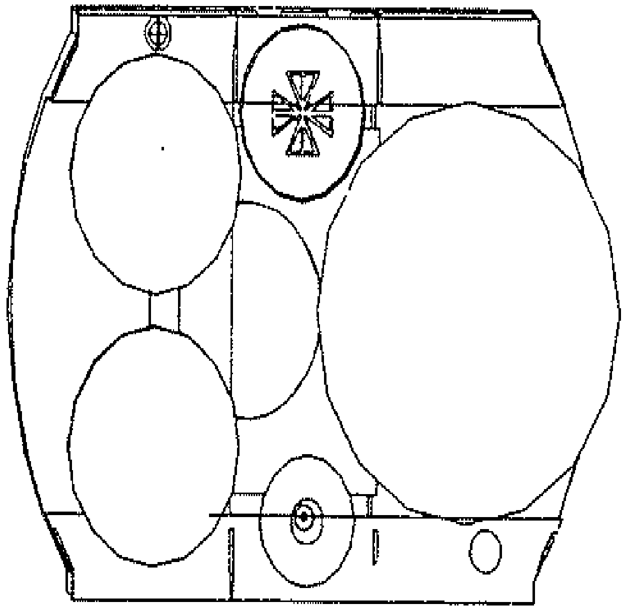


Figure 2.2-14. Top View of DSCS Spacecraft with 15" DIA E.C. Horn

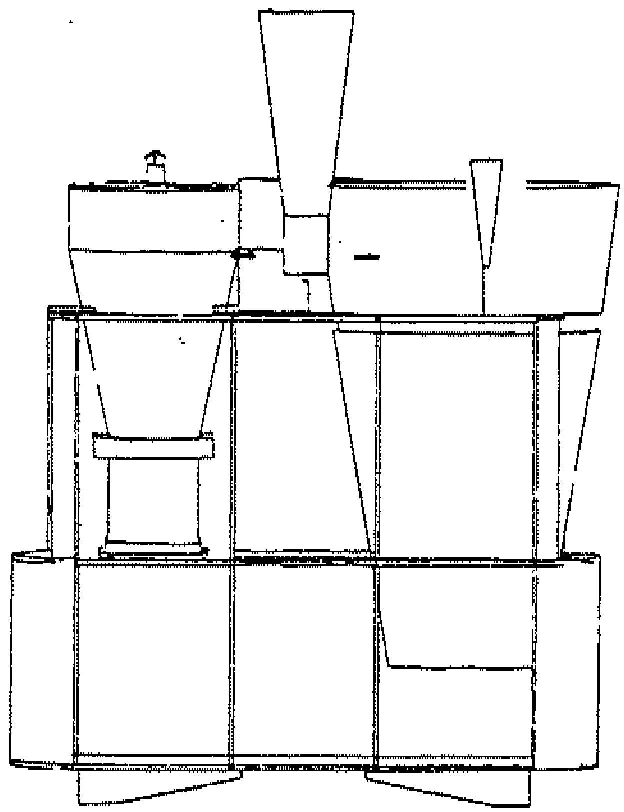


Figure 2.2-15. Side View of DSCS Spacecraft with 15" DIA E.C. Horn

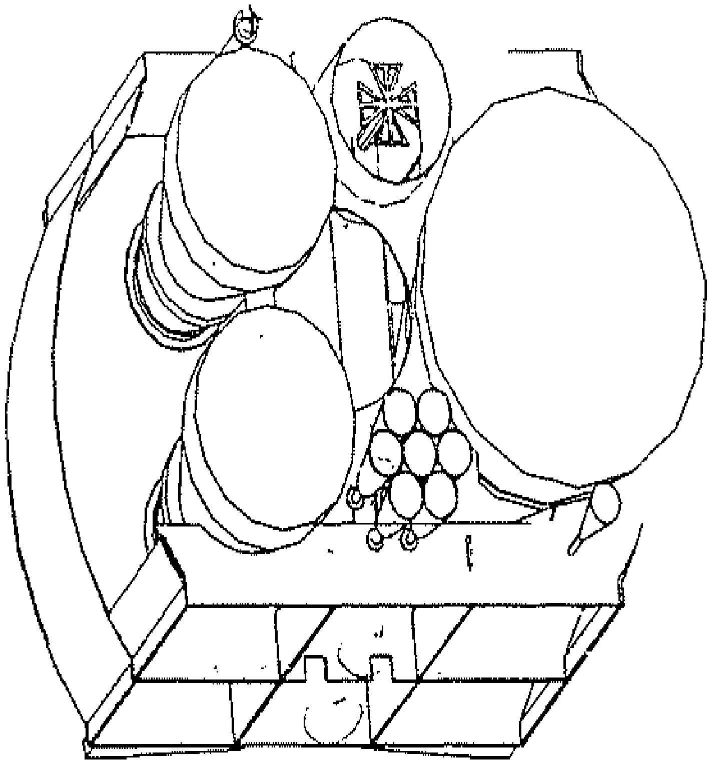


Figure 2.2-16. 3/4 View of DSCS Spacecraft with 7 Cluster E.C. Horn

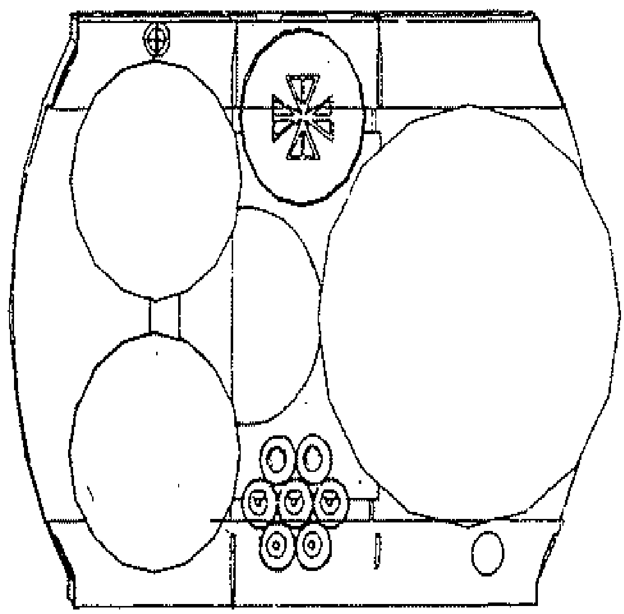


Figure 2.2-17. Top View of DSCS Spacecraft with 7 Cluster E.C. Horn

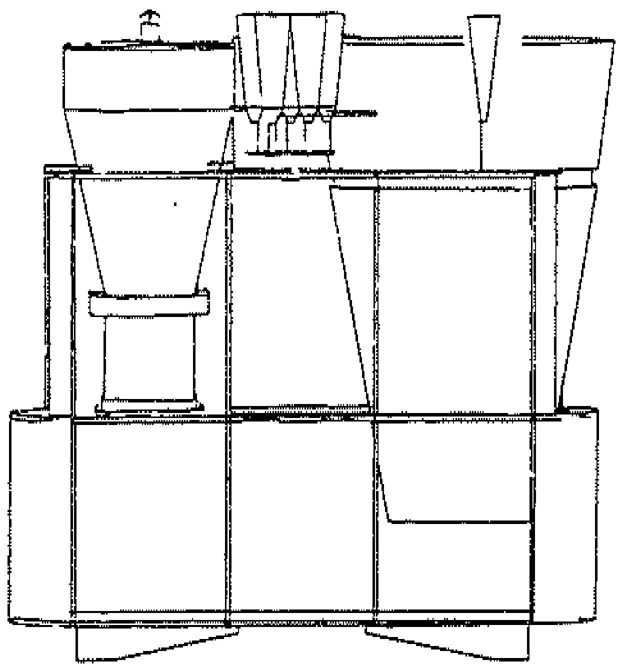


Figure 2.2-18. Side View of DSCS Spacecraft with 7 Cluster E.C. Horn

2.2.8 SCHEDULE

Figure 2.2-19 shows the development schedule. EM tests required of the new feed design are RF functional, radiation pattern, thermal cycle, post thermal, vibration, pyro shock, acceleration, and final functional. Lead time on electroformed parts is approximately six months. Protoflight tests will be conducted on an early flight unit. With a 1 Oct 86 go-ahead, a 22 month development cycle, and a 12 month manufacturing and test cycle, the earliest center body available for initial utilization is B14. Retrofit would be necessary for earlier utilization. In this case, special tests might be necessary to prove out the thermal design, since re-running spacecraft thermal vacuum would be very undesirable.

Based on the various configurations, the choice for this option B was two Multi Mode Horn 12" diameter and 30.3" long.

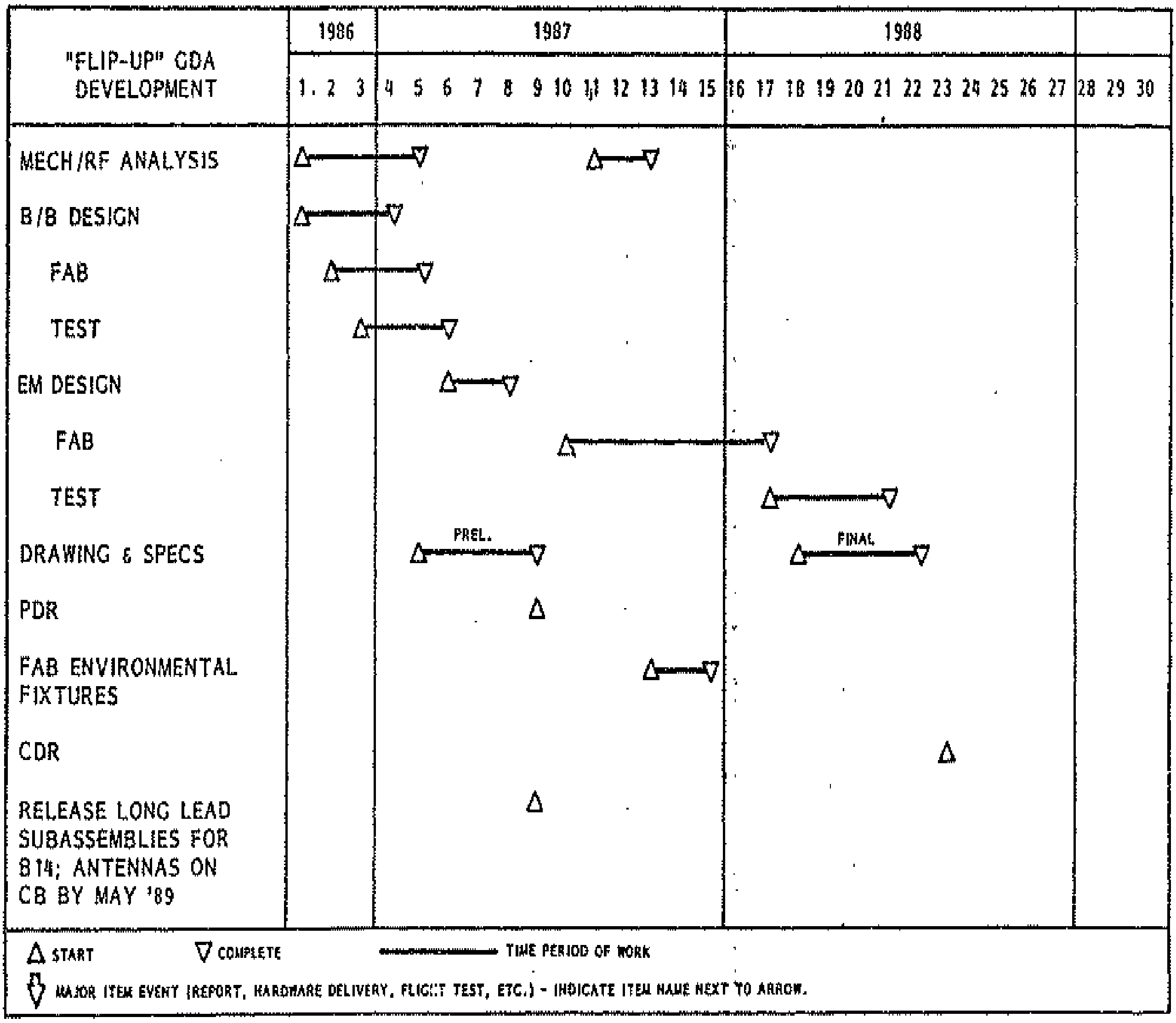


Figure 2.2-19. DSCS Task 20

2.3 STEERABLE KIDNEY COVERAGE ANTENNA

2.3.1 SELECTED APPROACH

In order to remove one 19 MBA from the DSCS spacecraft antenna cluster an antenna must be designed to provide coverage over a selected region of the Earth. This coverage pattern would be required to be compatible with the 19 MBA coverage patterns shown in Figure 2.3-1 through Figure 2.3-5. These patterns, provided by DCEC, are indicative of the most common coverage requirements of the MBA. Close inspection of the patterns indicates that the patterns can be provided by three basic beam shapes. The first pattern would provide approximately 20 dB gain over most of the Northern Hemisphere, as required in Figure 2.3-2, -3, and -5. A second beam shape would be required to provide approximately 18 dB gain over most of the Northern Hemisphere, as well as the southeastern quarter of the hemisphere (0° to -5° elevation and +1° to +9° azimuth), by what is best described as a kidney-shaped pattern. The third is similar to the second in that 18 dB coverage is again required over the Northern Hemisphere with a kidney-shaped pattern, this time extending to the southwest quadrant, similar to Figure 2.3-4. Beams 2 and 3 will be considered to be symmetric about the azimuth = 0° axis.

The implementation of the three beams can be accomplished most efficiently with an offset reflector system. The recommended offset reflector is a conductive composite, eighteen inches in diameter with integral stiffening ribs on the outer surface and an offset parabolic shape. The reflector assembly is similar in construction to the DSCS Gimballed Dish Antenna Assembly (GDA) reflector (47J246080). This allows the beam contours to be formed with a compact, lightweight structure. Figure 2.3-6 is a sketch of such a system with an offset parabolic reflector about 18 inches in diameter. The feed assembly would contain four feed horns similar to the 19 Multibeam Antenna (MBA) feed horns (47E234963), consisting of an electro-formed body with integral pins, fins, and bonded structural support collars. Two of the horns would be placed to provide coverage of the Northern Hemisphere as

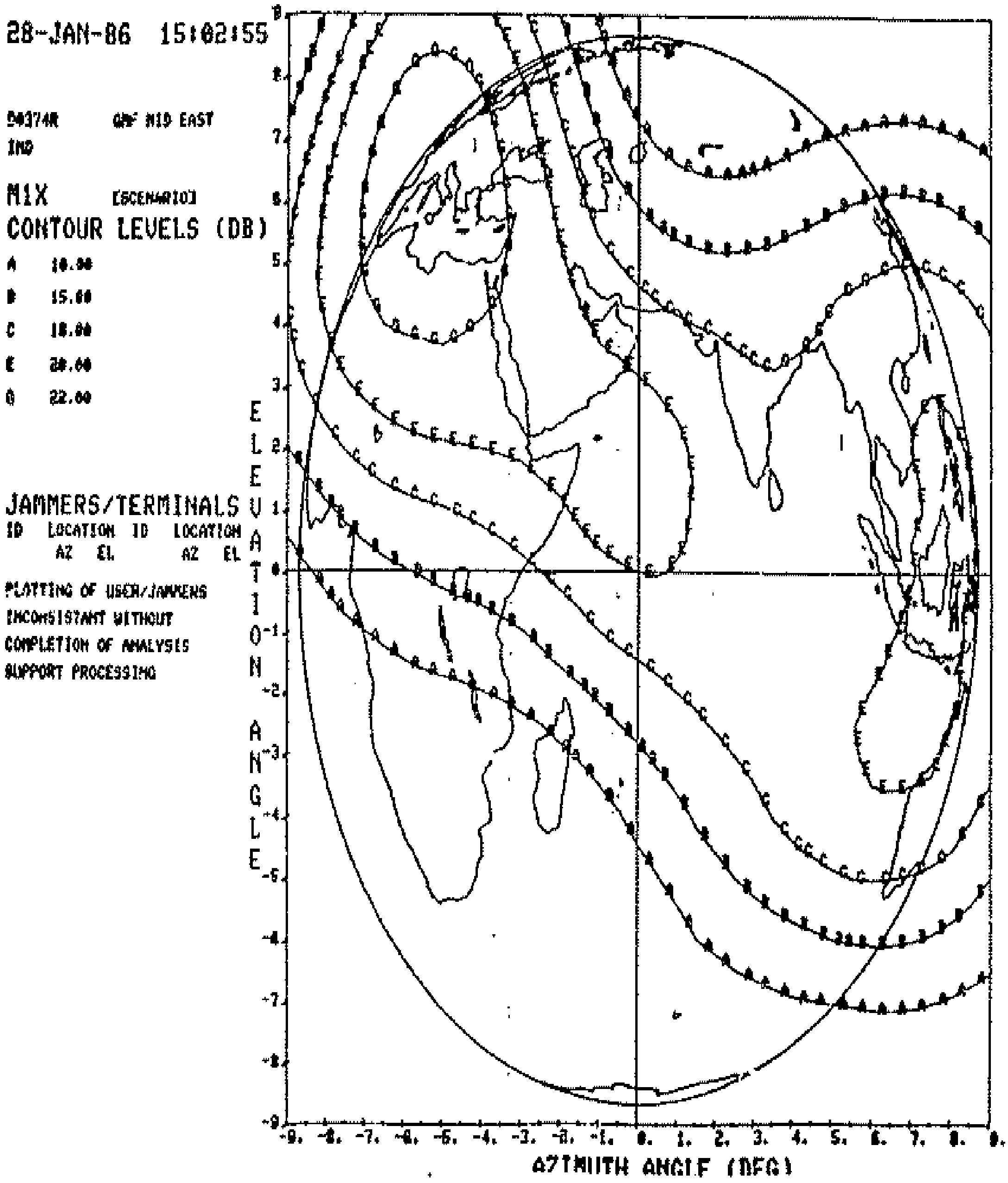


Figure 2.3-1. Typical IO Satellite Coverage Required

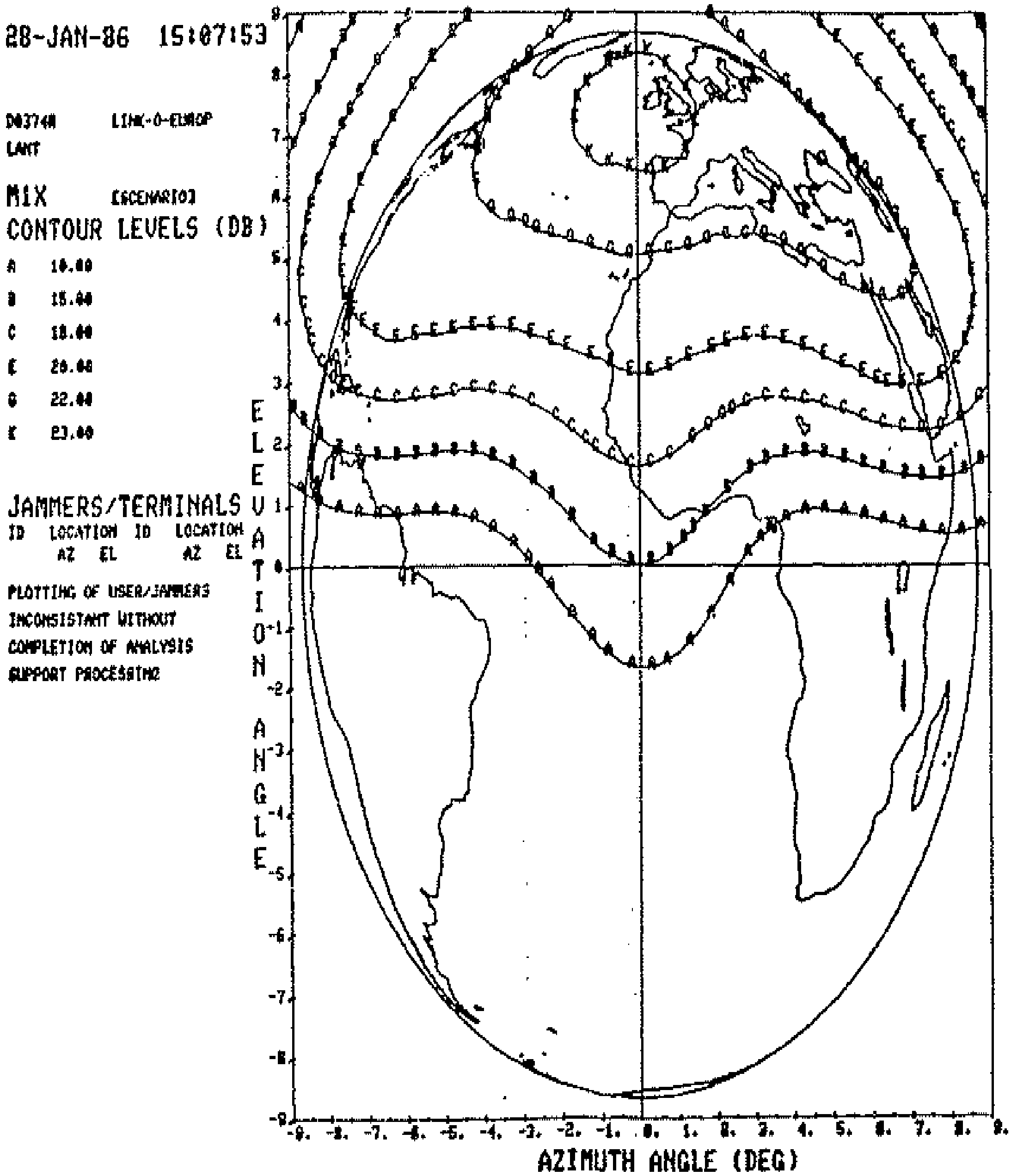


Figure 2.3-2. Typical ATL Satellite Coverage Required

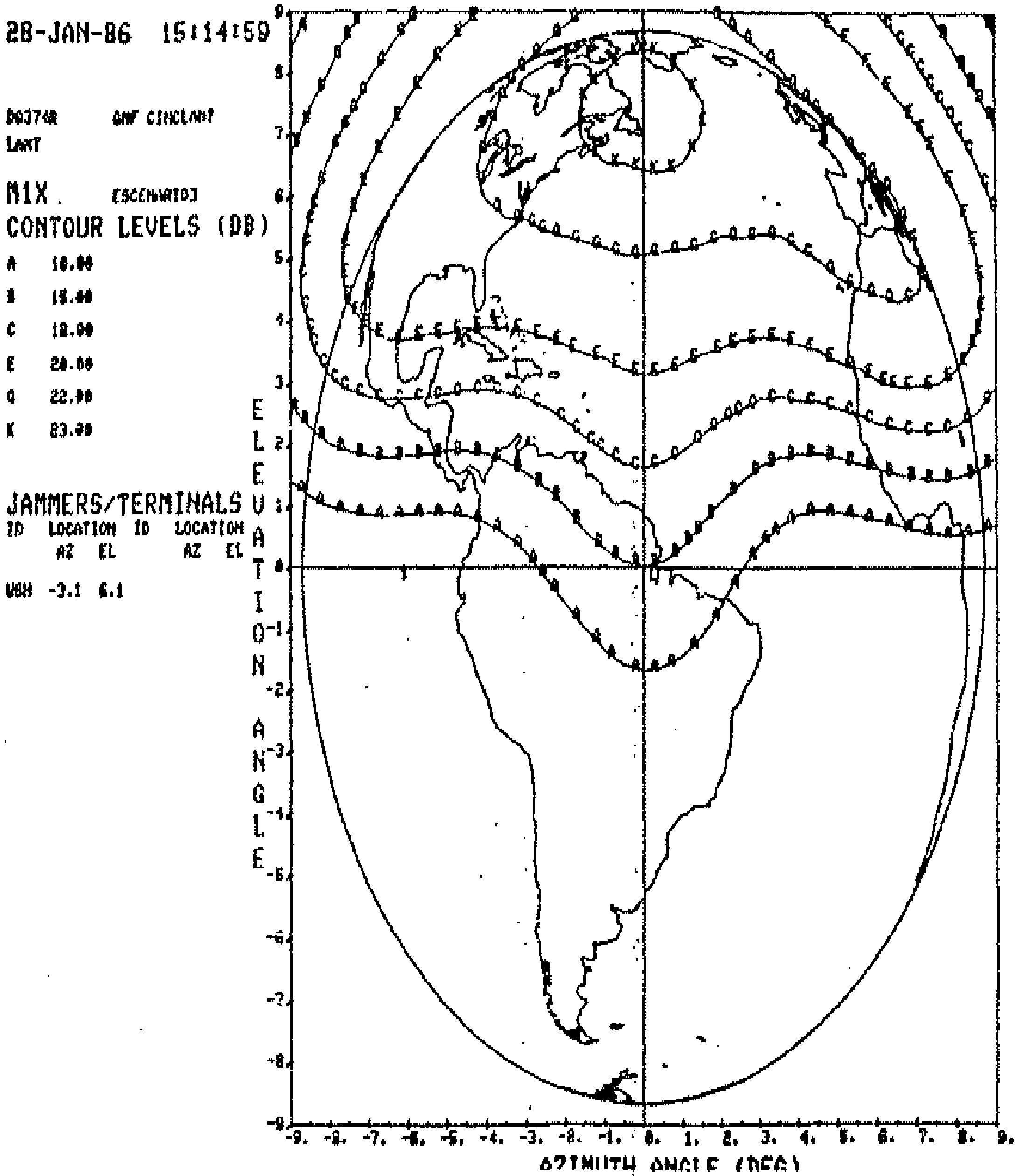


Figure 2.3-3. Typical WATL Satellite Coverage Required

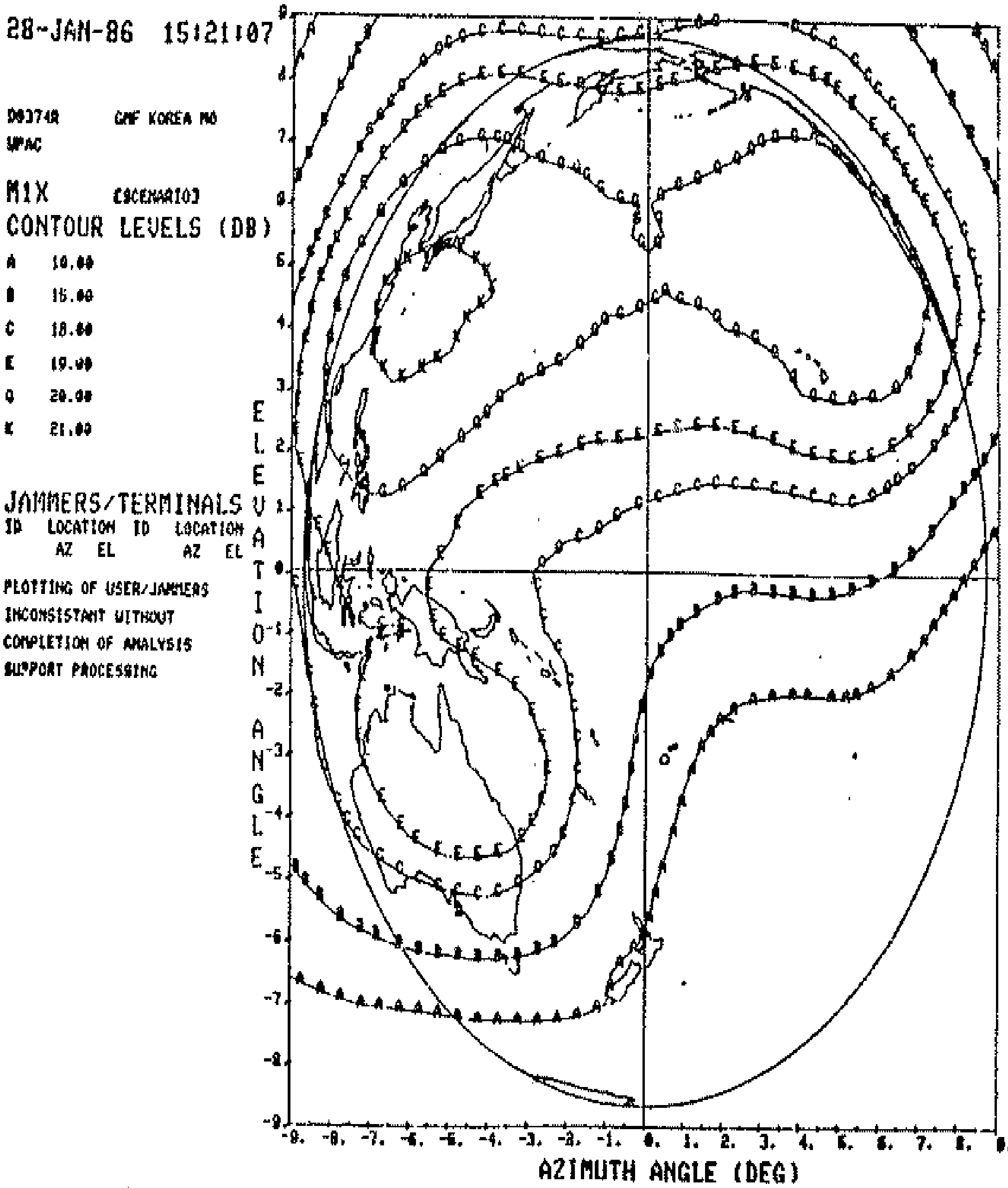


Figure 2.3-4. Typical WPAC Satellite Coverage Required

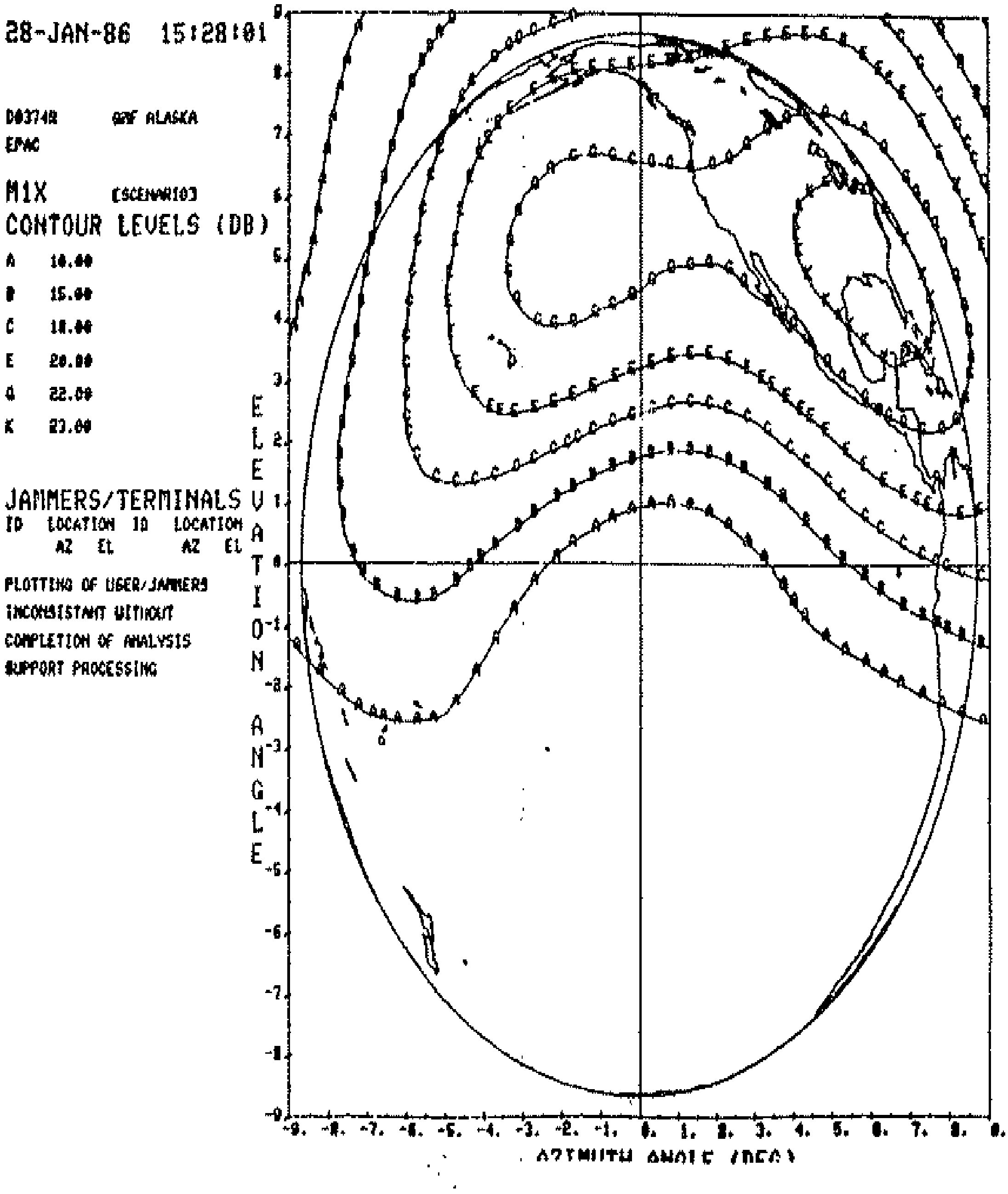


Figure 2.3-5. Typical EPAC Satellite Coverage Required

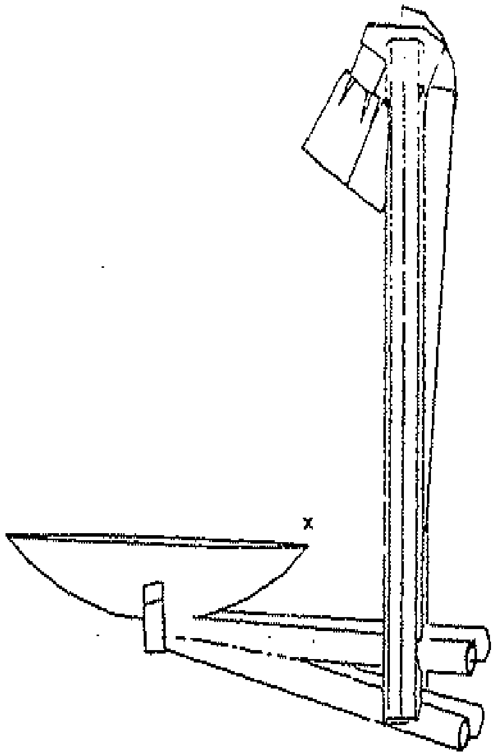


Figure 2.3-6A. Kidney Beam Antenna

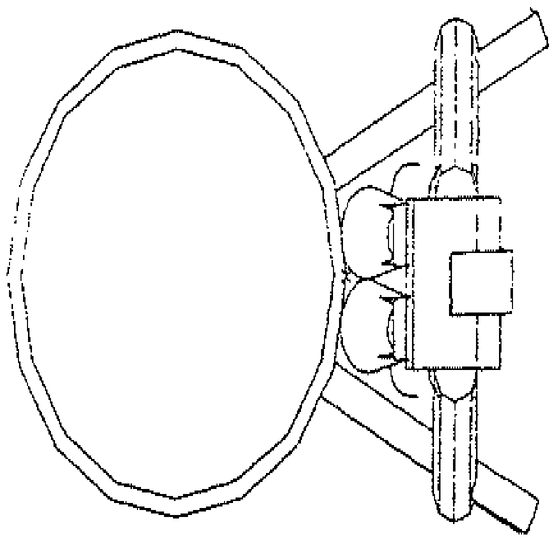


Figure 2.3-6B. Kidney Beam Antenna

required in each of the three beams (horns #1 and 2 in Figure 2.3-7). In order to provide the kidney-shaped beams (2 and 3), a DSCS VPD would be used to divert an appropriate level of power to either horn #3 or horn #4 through a switch for the direction required. Figure 2.3-8 is a simple schematic of the proposed feed system. The switch can be standard, off-the-shelf hardware, and the VPD, as mentioned, could utilize an existing DSCS VPD design. The structure used to mount the reflector to the honeycomb baseplate is a tubular composite strut assembly, similar to the GDA support structure (47J246064).

2.3.2 PERFORMANCE ESTIMATES

Utilizing well-proven computer programs available at GE a first approximation system was designed in order to identify the general performance levels to be expected as well as other typical design parameters. An 18 inch offset reflector with a 45° offset angle and F/D of one were used as baseline parameters. Four 2.9 inch diameter feeds were used as a baseline with the resultant beam positions for each individual feed shown in Figure 2.3-9.

Based upon information provided by the Air Force, Figure 2.3-10 through 2.3-15 were generated to provide performance estimates. Figure 2.3-10 shows an Atlantic satellite location with a single spot beam placed on the Washington DC area as a typical application. For this and all remaining figures (2.3-10 thru 2.3-15) the gain levels have been adjusted to include .5 dB beam form network loss. Figure 2.3-11 shows northern hemispheric coverage with equal power in beams 1 and 2. Figures 2.3-12 and 2.3-13 show two different amplitude tapers with the same beams to provide coverage for the typical locations as shown. Figure 2.3-14 and 2.3-15 show two typical variations in the Kidney beam performance based upon different power tapers. These show that the required beam shapes are possible given the general offset reflector dimensions.

It is important to note that the patterns shown were generated as a first approximatation and are not optimized. The feedhorn sizes and spacing could be varied to increase coverage in desired locations. For example, beams 3 and

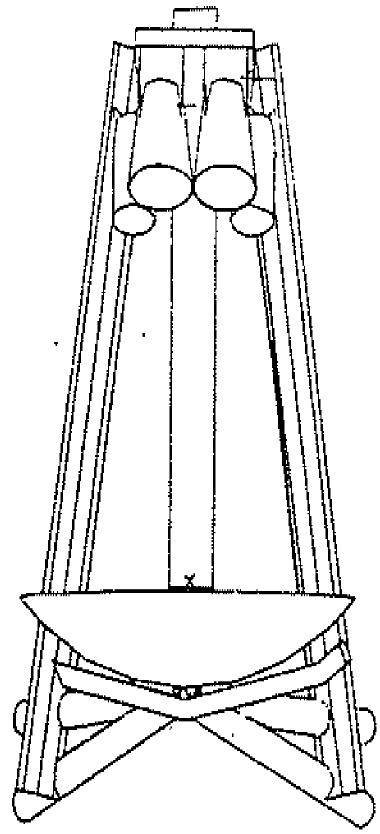


Figure 2.3-7. Kidney Beam Antenna

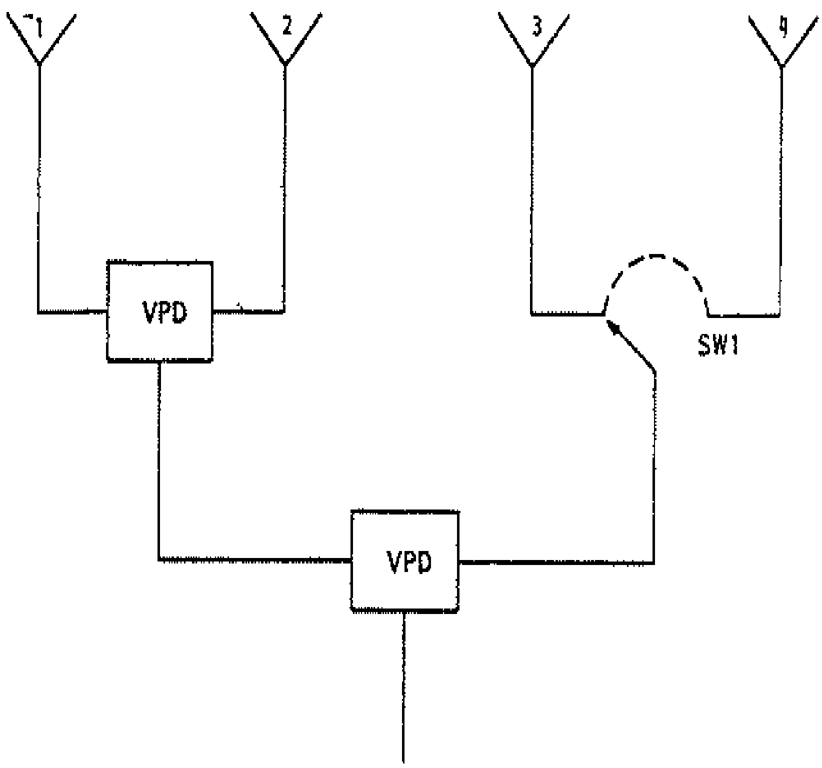


Figure 2.3-8. Antenna Feed Network

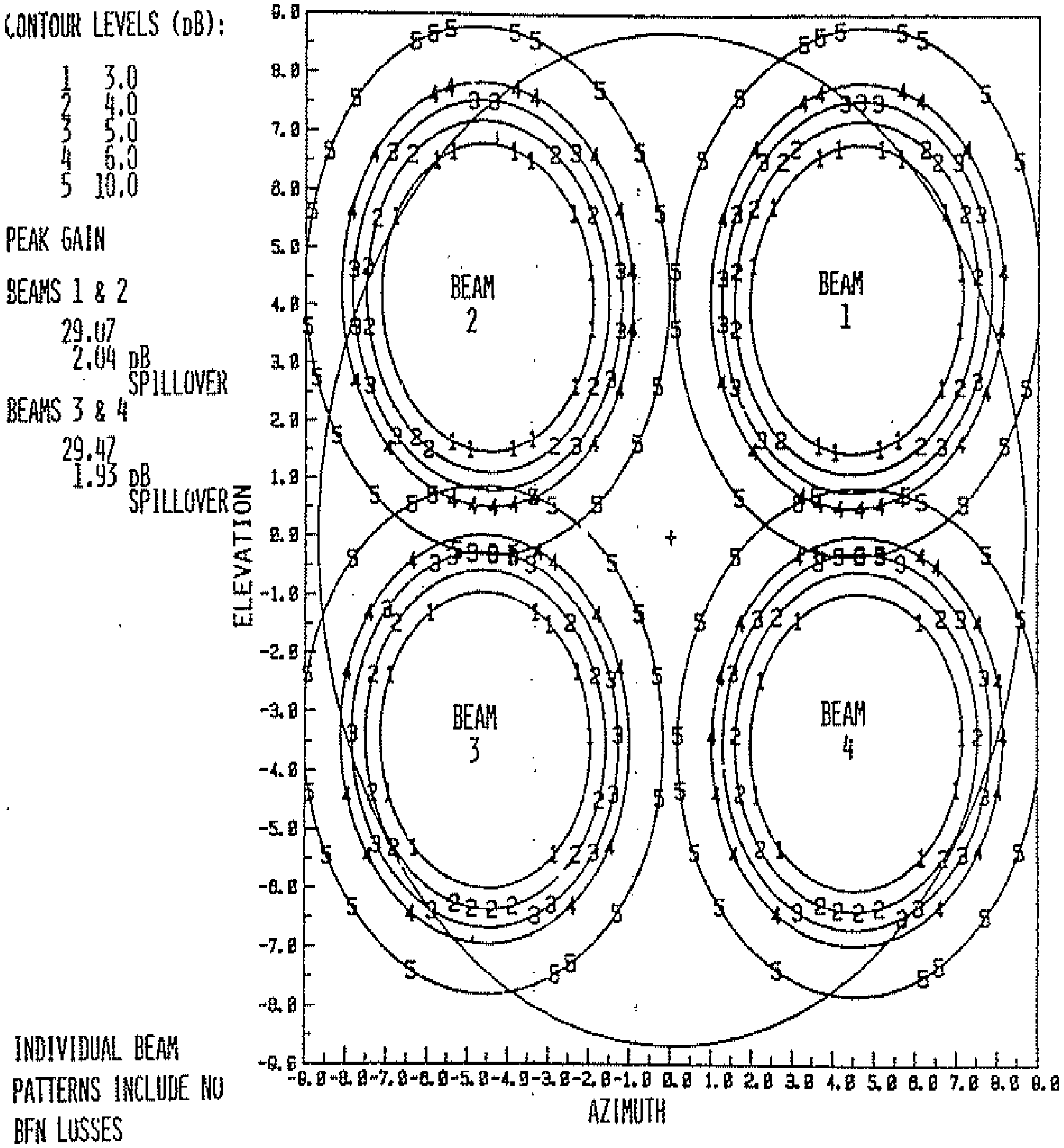

CONTOUR LEVELS (dB):
1 3.0
2 4.0
3 5.0
4 6.0
5 10.0
PEAK GAIN
BEAMS 1 & 2
29.07
2.04 dB SPILLOVER
BEAMS 3 & 4
29.47
1.93 dB SPILLOVER
INDIVIDUAL BEAM PATTERNS INCLUDE NO BFN LOSSES
BEAM 1
BEAM 2
BEAM 3
BEAM 4
ELEVATION
AZIMUTH

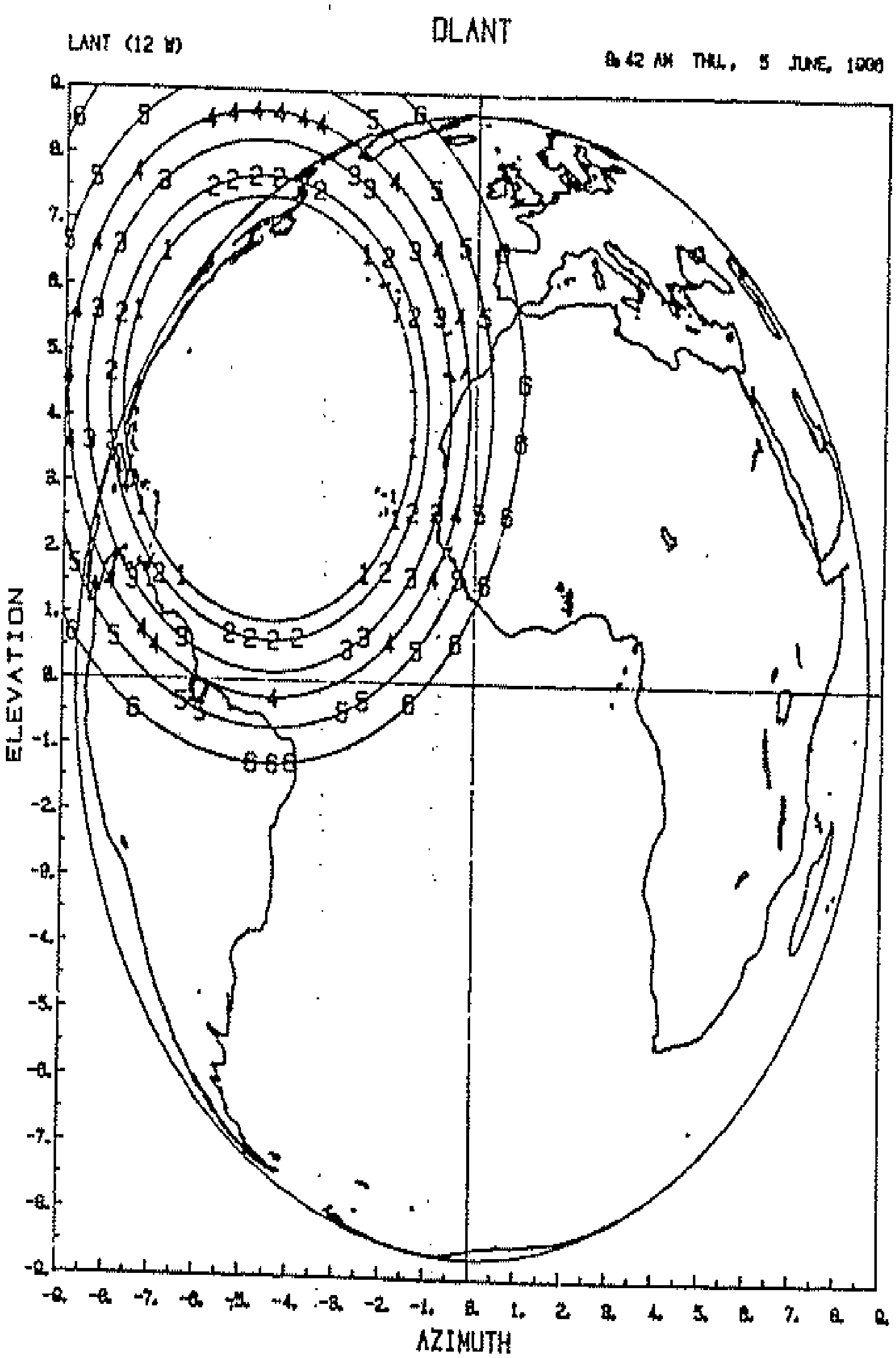
Figure 2.3-9.

CONTOUR LEVELS (dB):

1 24.00
2 23.00
3 21.00
4 19.00
5 16.00
6 11.00

POWER DIVISION

BEAM 1 OFF
BEAM 2 1.0
BEAM 3 OFF
BEAM 4 OFF



PATTERN INCLUDES .5 dB
BFN LOSSES

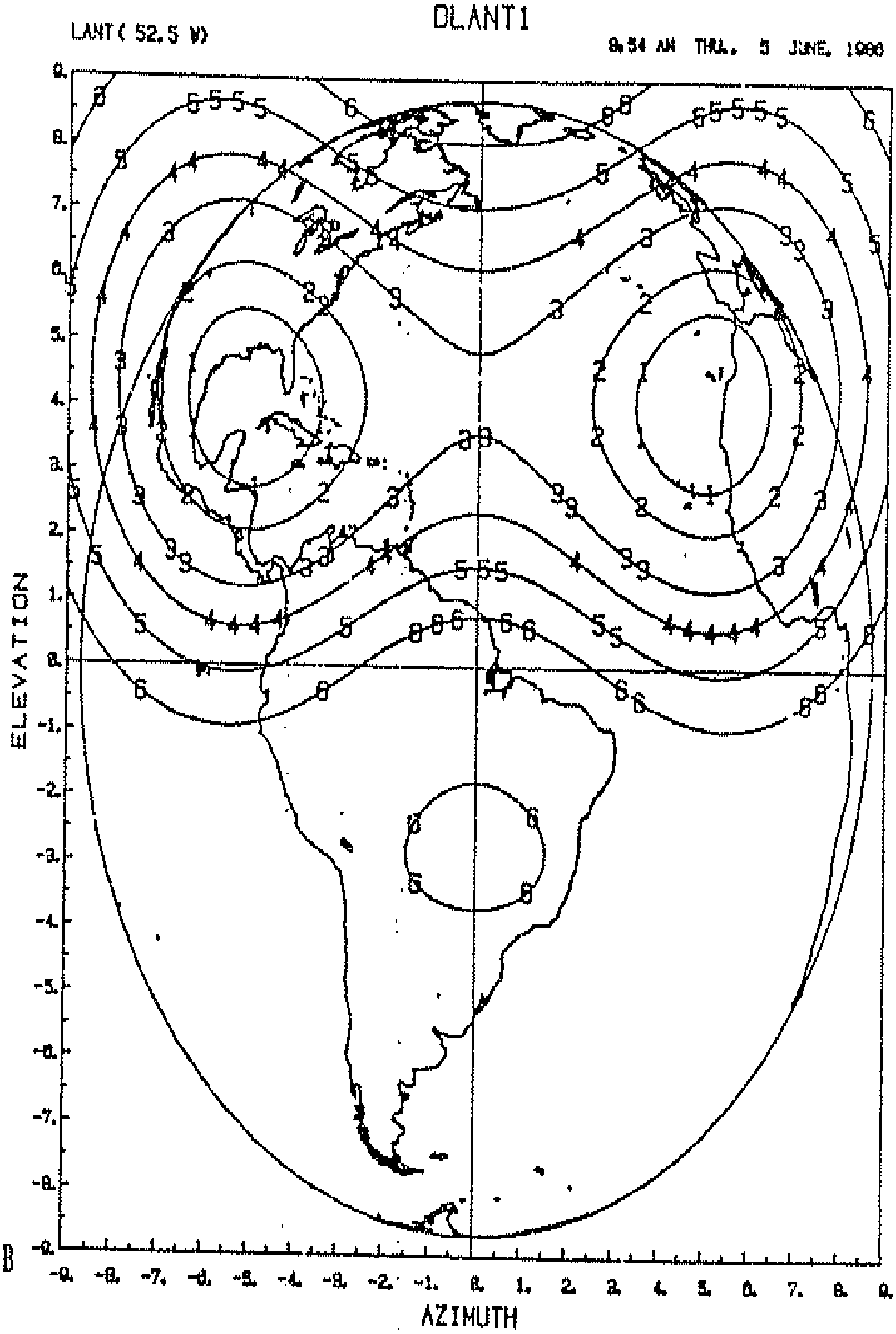
Figure 2.3-10.

CONTOUR LEVELS (dB):

1 24.00
2 23.00
3 21.00
4 19.00
5 16.00
6 11.00

POWER DIVISION

BEAM 1 .50
BEAM 2 .50
BEAM 3 OFF
BEAM 4 OFF



PATTERN INCLUDES .5 dB
BFN LOSSES

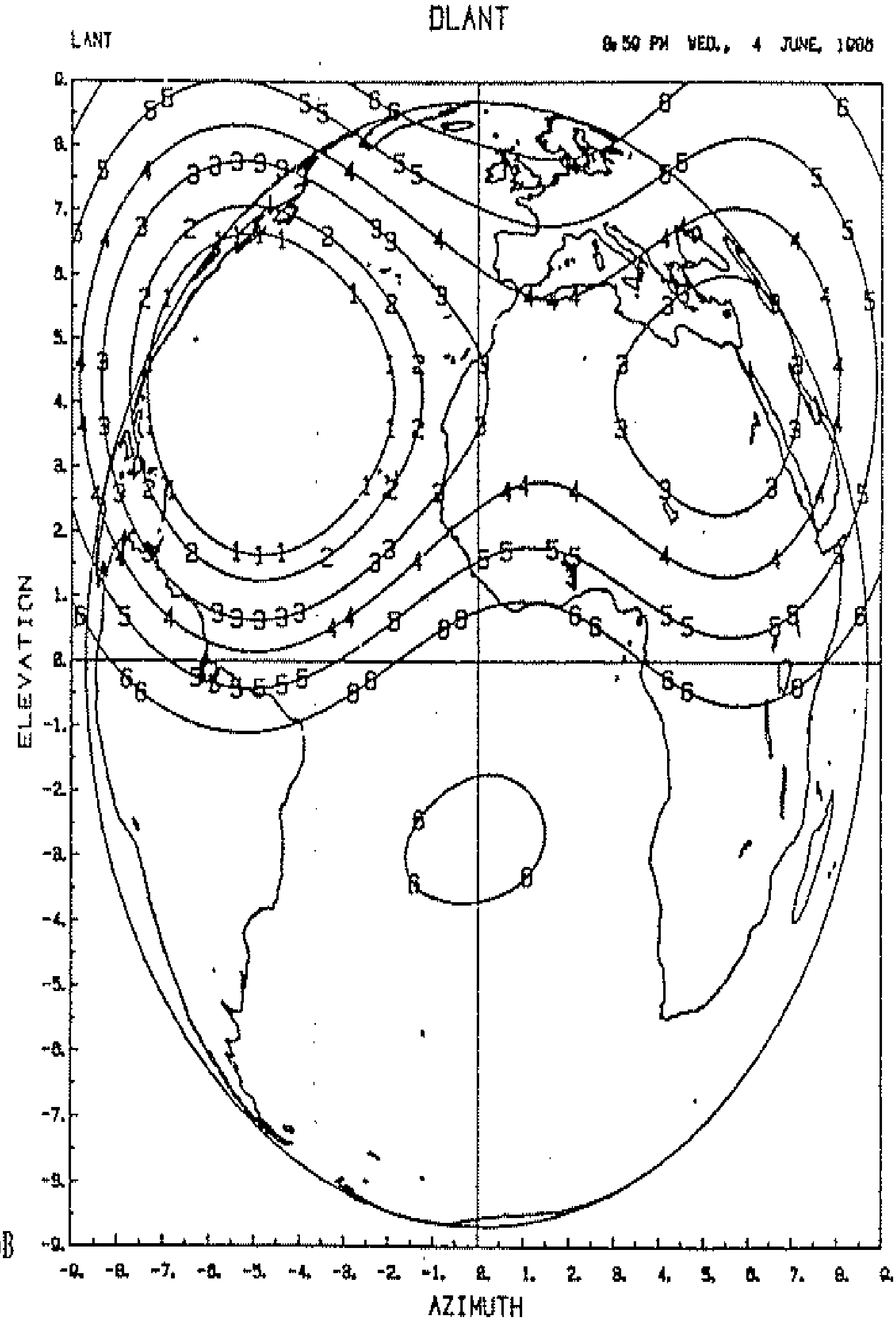
Figure 2.3-11.

CONTOUR LEVELS (dB):

1 24.00
2 23.00
3 21.00
4 19.00
5 16.00
6 11.00

POWER DIVISION

BEAM 1 .3
BEAM 2 .7
BEAM 3 OFF
BEAM 4 OFF



PATTERN INCLUDES .5 dB
BFN LOSSES

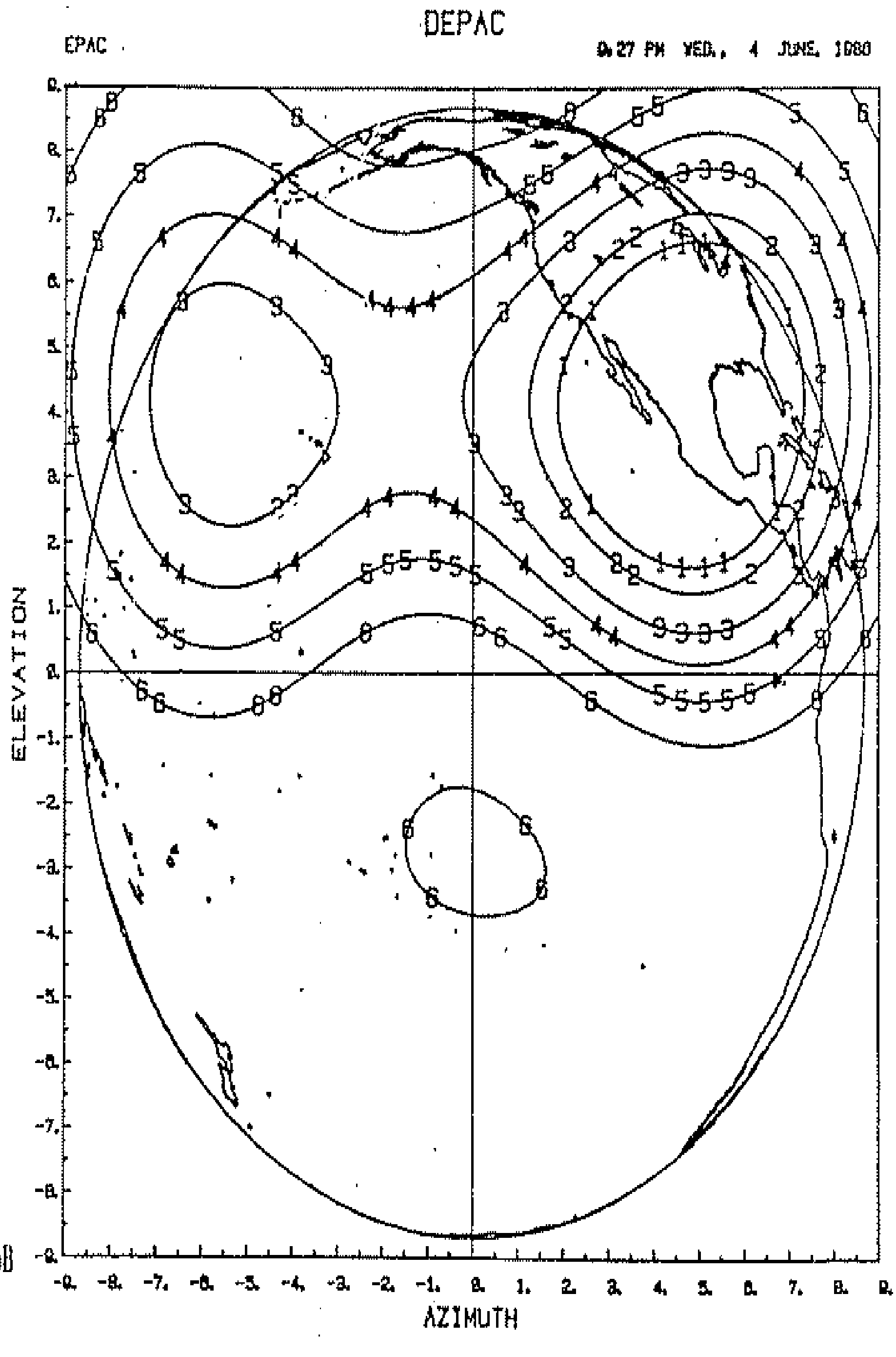
Figure 2.3-12.

CONTOUR LEVELS (dB):

1	24.00
2	23.00
3	21.00
4	19.00
5	16.00
6	11.00

POWER DIVISION

BEAM 1	.7
BEAM 2	.3
BEAM 3	OFF
BEAM 4	OFF



PATTERN INCLUDES .5 dB BFN LOSSES

Figure 2.3-13.

WP1098/816.2-277/NC

CONTOUR LEVELS (dB):

1	23.00
2	21.00
3	19.00
4	16.00
5	11.00

POWER DIVISION

BEAM 1	.25
BEAM 2	.5
BEAM 3	OFF
BEAM 4	.25

PATTERN INCLUDES .5 dB BFN LOSSES

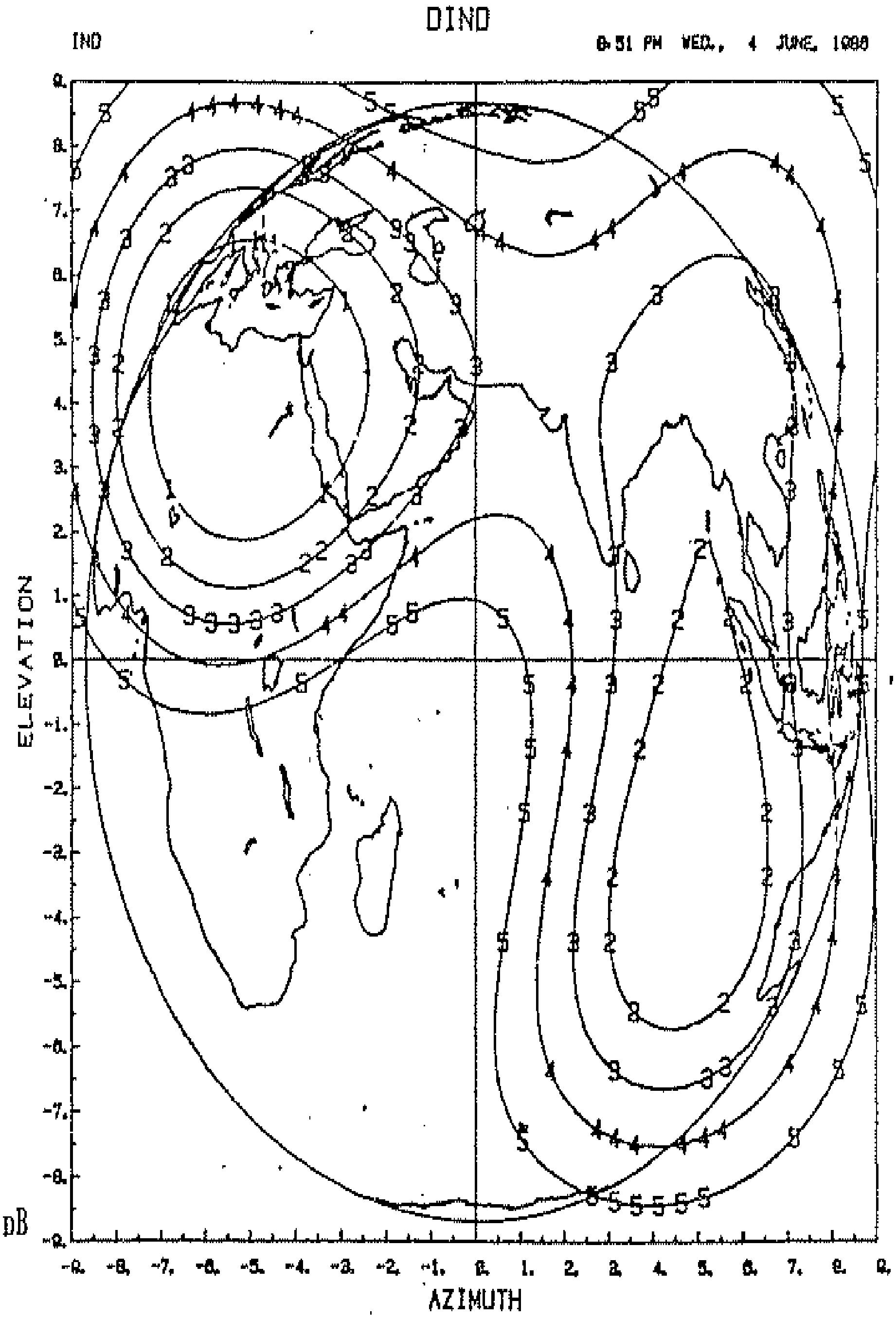


Figure 2.3-14.

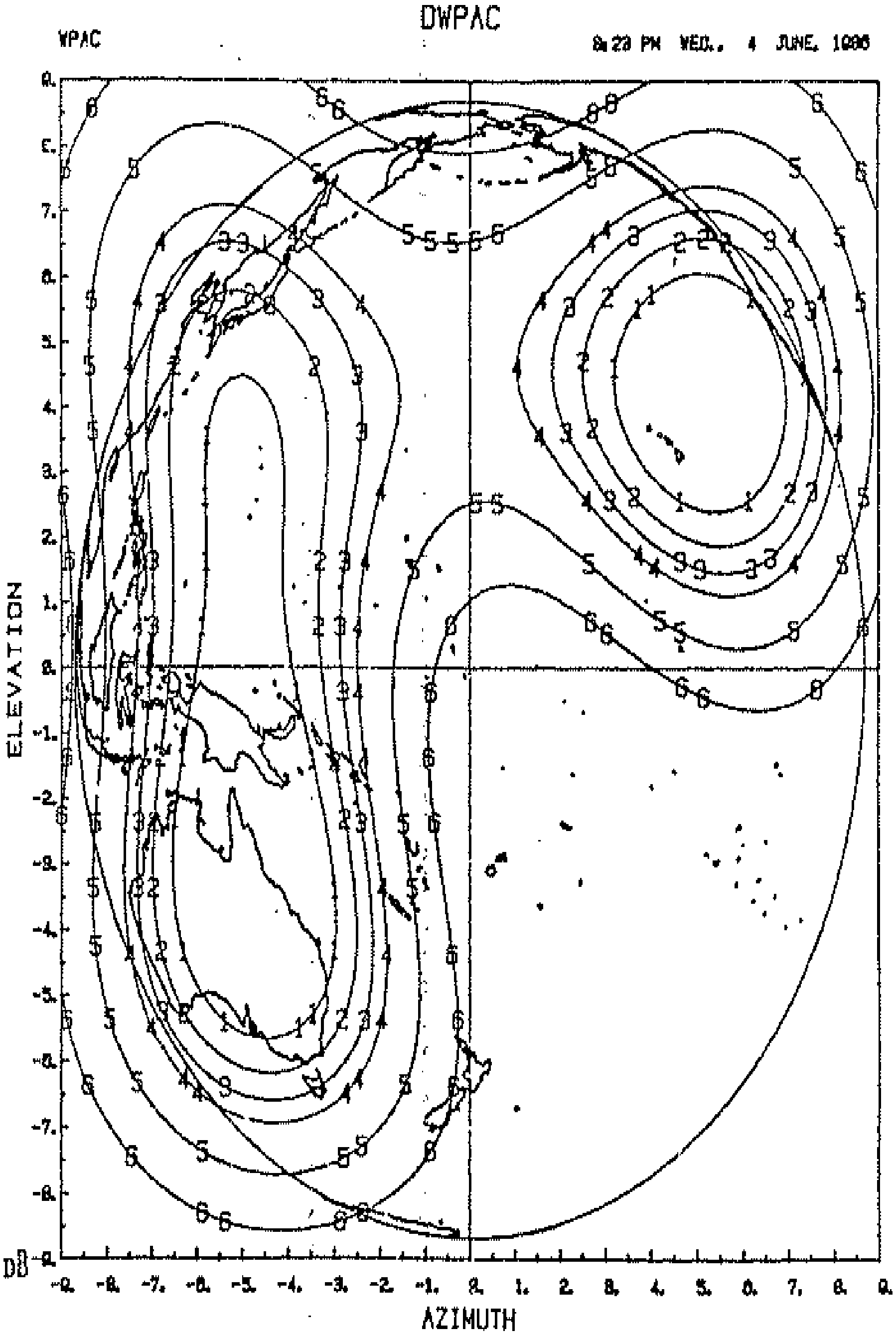
WF1098/816.2-277/NC

CONTOUR LEVELS (dB):

1	22.00
2	21.00
3	20.00
4	19.00
5	16.00
6	11.00

POWER DIVISION

BEAM 1	.33
BEAM 2	.33
BEAM 3	.33
BEAM 4	OFF



PATTERN INCLUDES .5 dB BFN LOSSES

Figure 2.3-15.

4 might be more outward toward the edge of earth to provide additional edge coverage, while sacrificing gain around Az = 0°. As shown in the figures, the power levels may also be varied to optimize the various pattern performance levels. The dish size and shape may also be varied to change the values of gain at the crossover levels between beams depending upon the requirements. A short analytical effort would be required to determine the exact reflector and feed dimensions, locations, and power levels once GE has received an adequate description for the most desired pattern requirements for each satellite location.

A short design phase, fabrication of a breadboard, and a single interation should be adequate to firm up all of the required design dimensions for such a system. The system can be considered as a direct functional replacement for one of the 19 MBA's for the three required beam positions.

The total antenna weight breakdown is listed in Table 2.3-1. The reflector, baseplate, and all support structure are of composite construction in order to maintain the rigidity of the reflector/feed horn interface and to minimize the weight.

Two components in the antenna system are active, the VPD and waveguide switch, and their combined dissipation is less than 1 watt. These components would be activated during initial configuration (depending upon satellite location) and would not require any further reconfiguration.

Table 2.3-1. Steerable Kidney Coverage Antenna Weight Table

Item	Quantity	Total Weight
Reflector	1	2.2 lbs
Reflector Support	1	.5
Feed Horns	4	0.6
Waveguide Assemblies	7	1.0
Variable Power Divider	1.	4.6
Waveguide Switch	1	0.5
Honeycomb Base	1	2.0
Waveguide and Feed Horn Support	-	.6
	TOTAL	12.0

2.3.3 IMPACTS

This switched system would replace the control electronics for one of the MBA's with a simple control. The new CE could only be required to decode a command to choose one of the three preset beam settings, as opposed to the MBA CE which must decode a very large number of beam combinations by decoding the required settings for each of the 19 feed horn VPD controls. This represents a significant savings in complexity. Alternate schemes to provide more flexibility with more VPD's are possible and further study may show these to be desirable.

2.3.4 RISKS

As mentioned previously, the design of the selected approach represents no new technology risk. The design can be accomplished with existing analytical techniques, and the fabrication can utilize existing DSCS designs (VPD) and

off-the-shelf parts (switch and power dividers). The feed horns and reflector can be fabricated using techniques similar to the DSCS GDA.

2.3.5 RATIONALE FOR SELECTION - ALTERNATE APPROACHES

The offset fed reflector system was chosen as the selected approach since it is the only reasonable method to achieve the contoured kidney-shaped beam desired for beams 2 and 3. Other approaches, such as a feed horn cluster, would be extremely difficult to design and fabricate, as well as occupy nearly as much area as the current MBA. The other approach would be a lens similar to an existing MBA.

As an alternative to the kidney-shaped pattern, a trade off was also conducted to examine the option of a steerable (mechanically) hemispherical coverage horn and the option of replacing the MBA BFN with a set of discrete switches which would be configured to allow only Northern or Southern Hemisphere coverage (with no other pattern options). Figure 2.3-16 through Figure 2.3-19 show the various patterns which could be obtained by configuring a 19 MBA horn and lens cluster into a "hard wired" beam. The patterns represent antenna gain with the heavy contour representing 20 dBi. Rows 3, 4 and 5 all "on" would provide the best hemispheric coverage, with the system loss of a switch network estimated at .7 dB, or about 1.3 dB less than the 2 dB BFN losses with the current configuration. As a rule of thumb, hard wire switches would allow about 1 dB improvement over a similar BFN pattern with the obvious loss in functional flexibility.

The other option considered, that of a steerable hemispheric coverage horn, looks to be both practical and feasible. Simple computer analysis (Figure 2.3-20 through Figure 2.3-23) shows the horizontal and vertical cut patterns of an eliptical-shaped horn designed to provide a minimum of 20 dB gain over either the Northern or Southern Hemisphere. Figure 2.3-24 shows the 20 dBi contour superimposed on the Earth. The total weight breakdown is listed in Table 2.3-2. Approximately four mechanical beam positions would be required to provide full Earth coverage. The mechanical design would use the

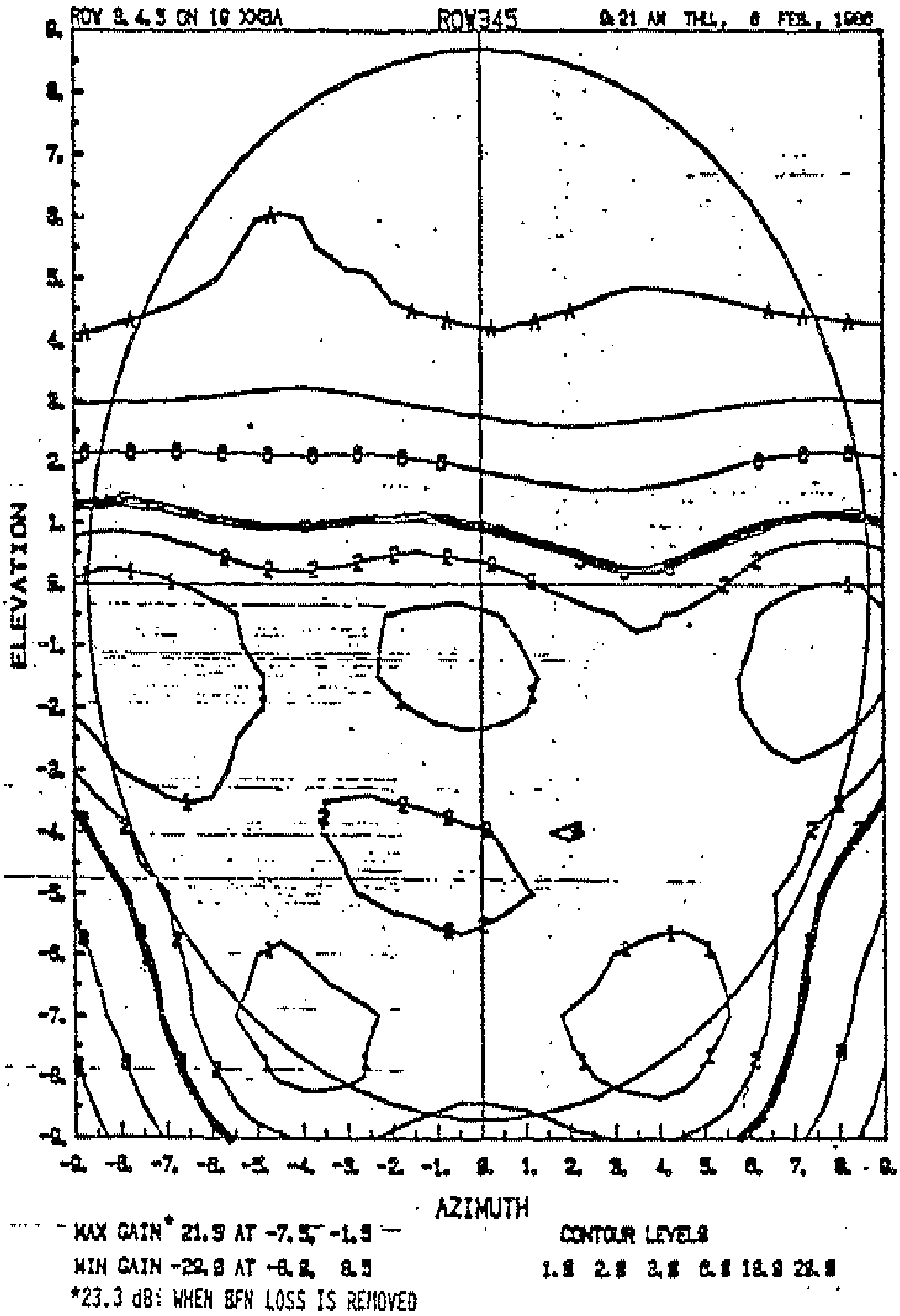


Figure 2.3-16. Transmit MBA Pattern

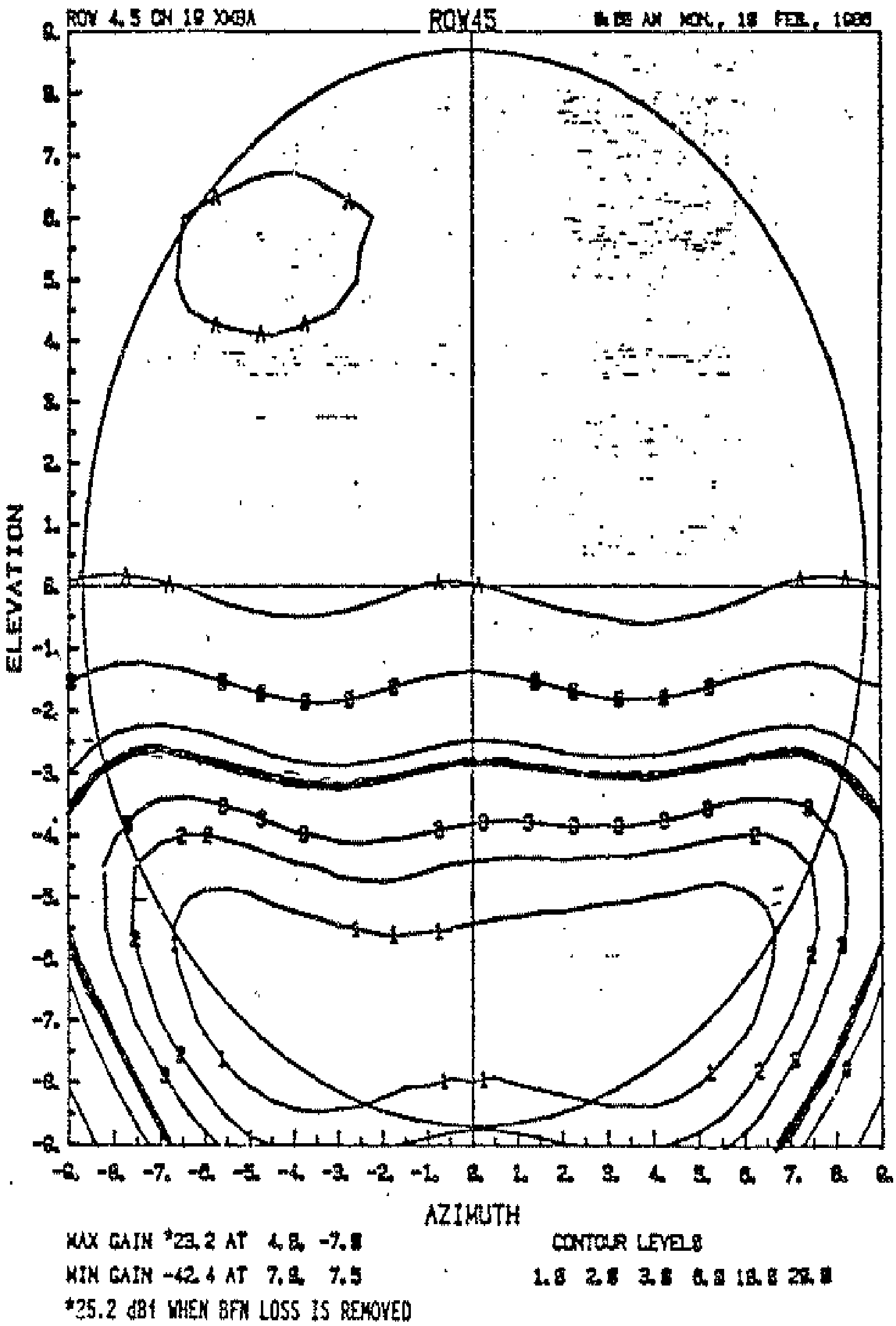


Figure 2.3-17. Transmit MBA Pattern

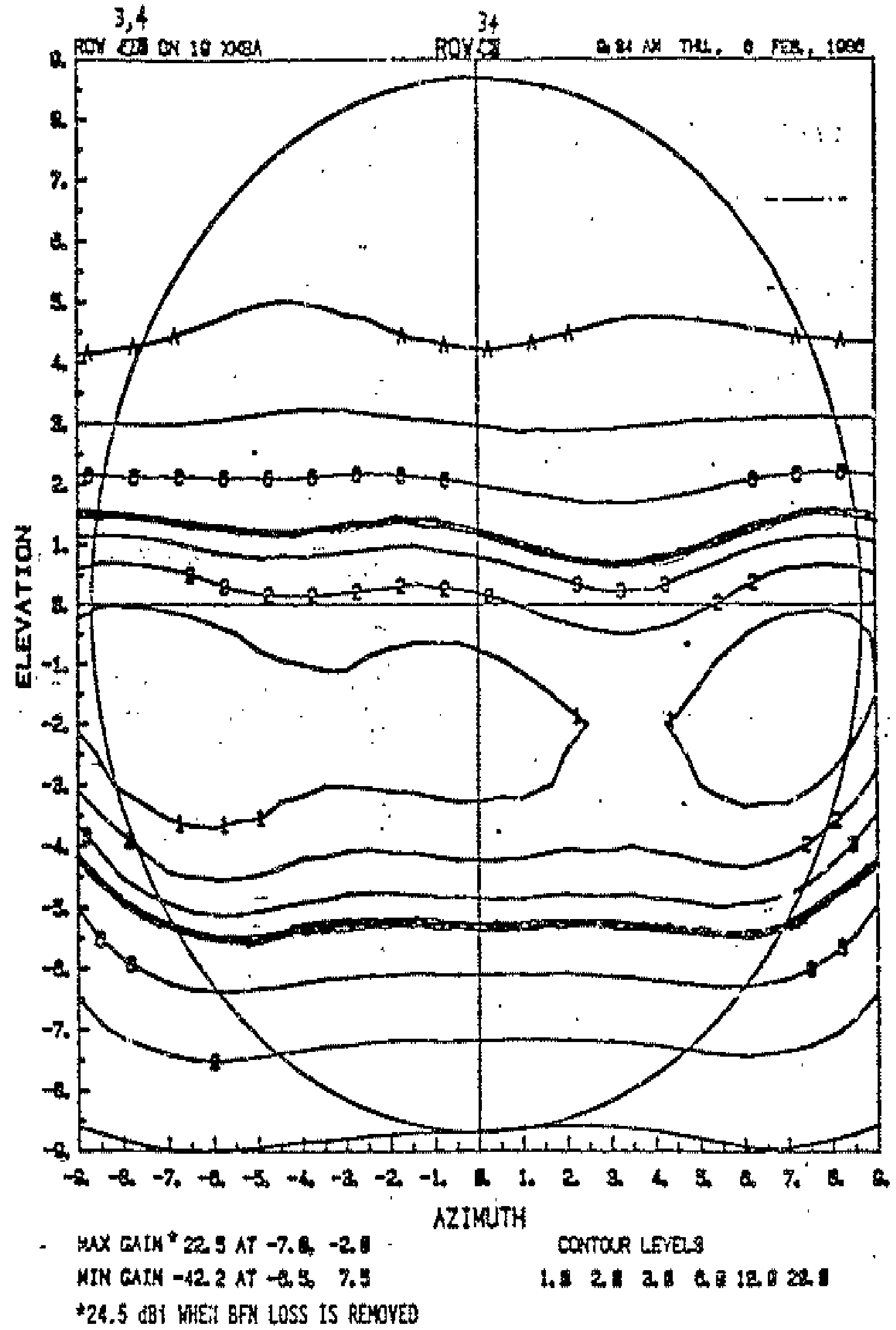


Figure 2.3-18. Transmit MBA Pattern

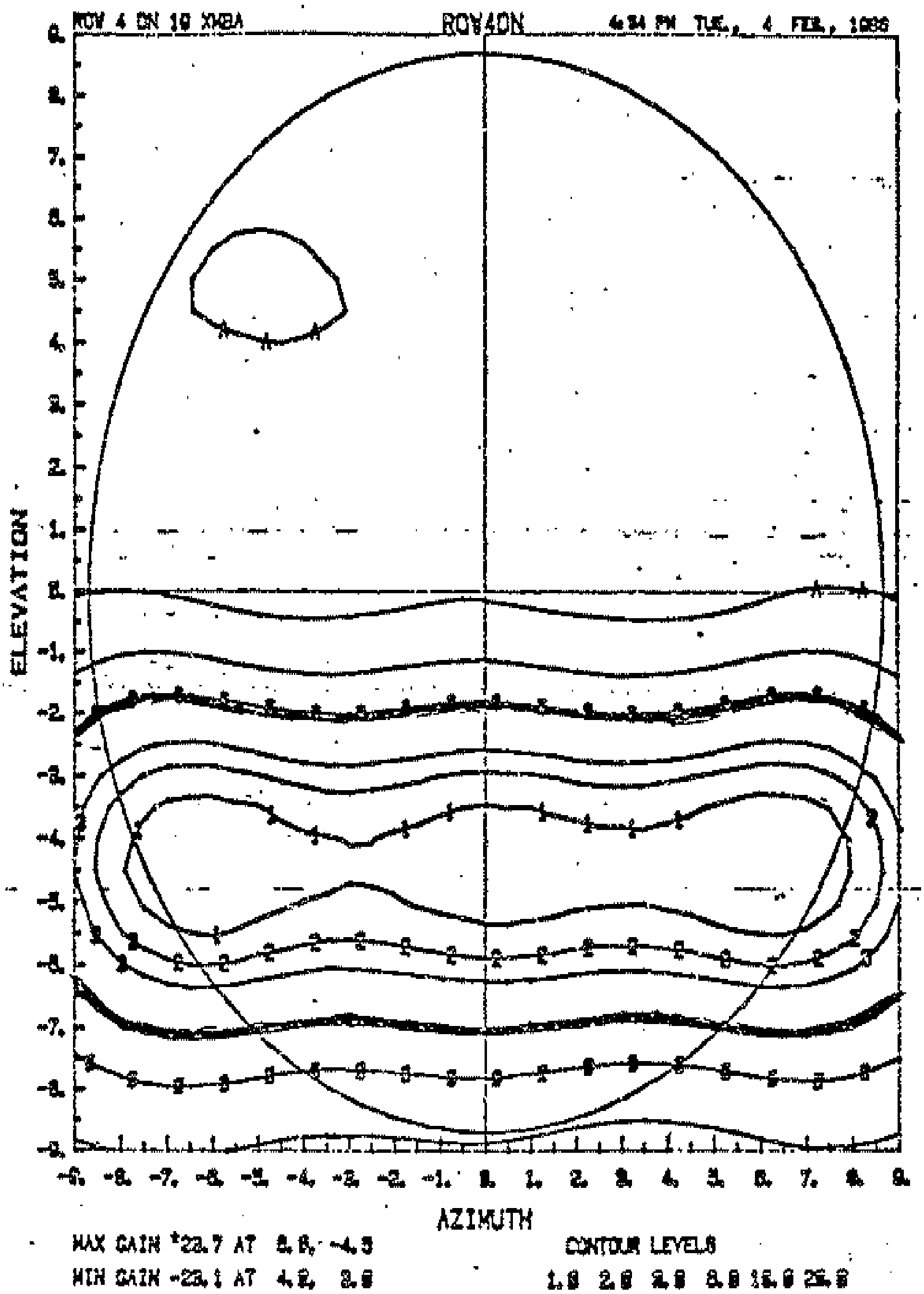


Figure 2.3-19. Transmit MBA Pattern

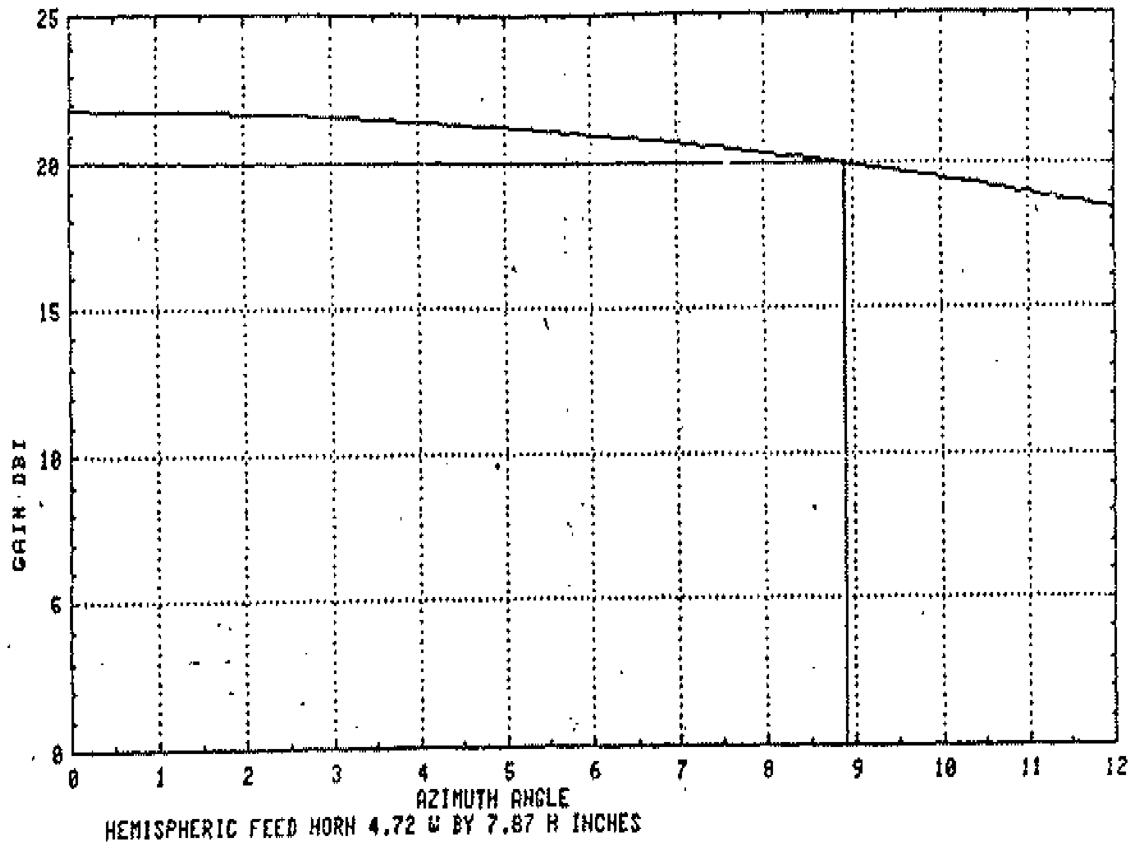


Figure 2.3-20. Hemispherical Horn Pattern Azimuth Pattern to 12°

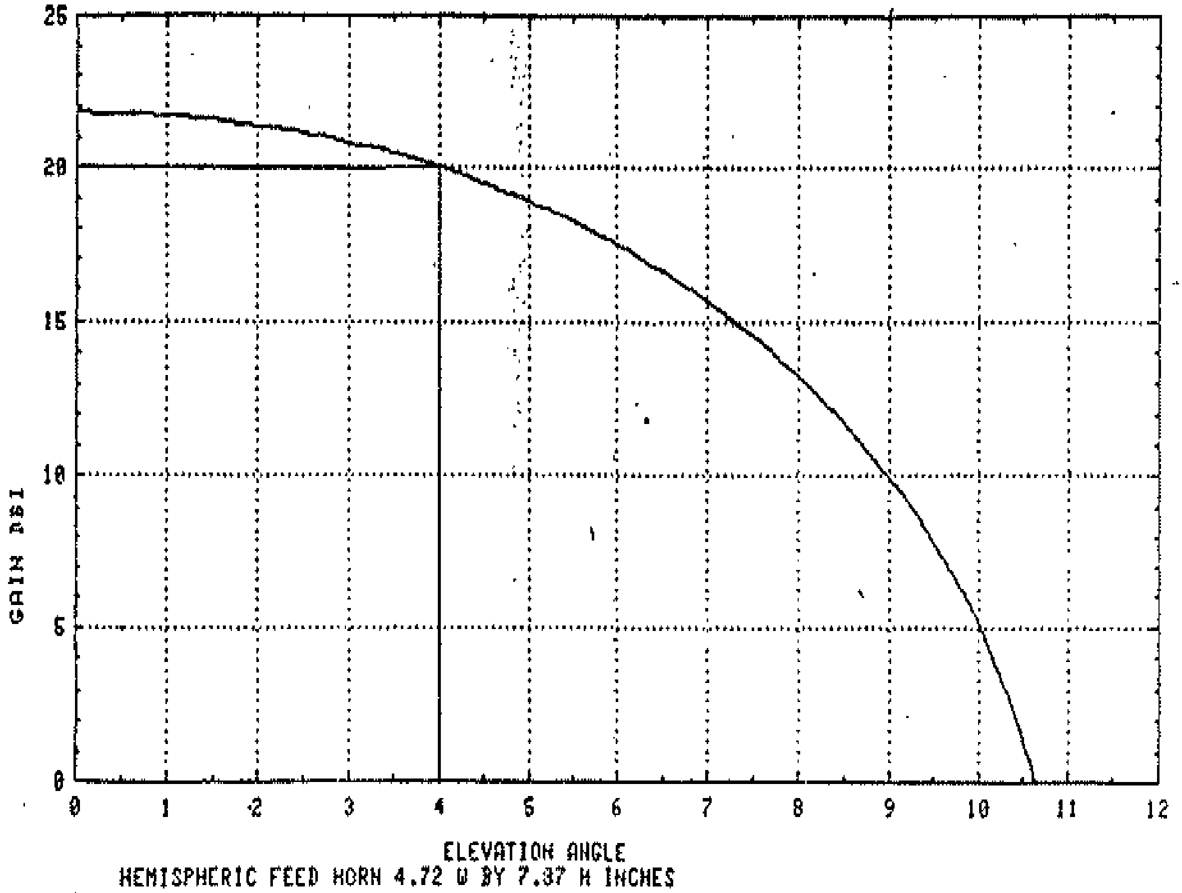


Figure 2.3-21. Hemispherical Horn Pattern - Elevation Pattern to 12°

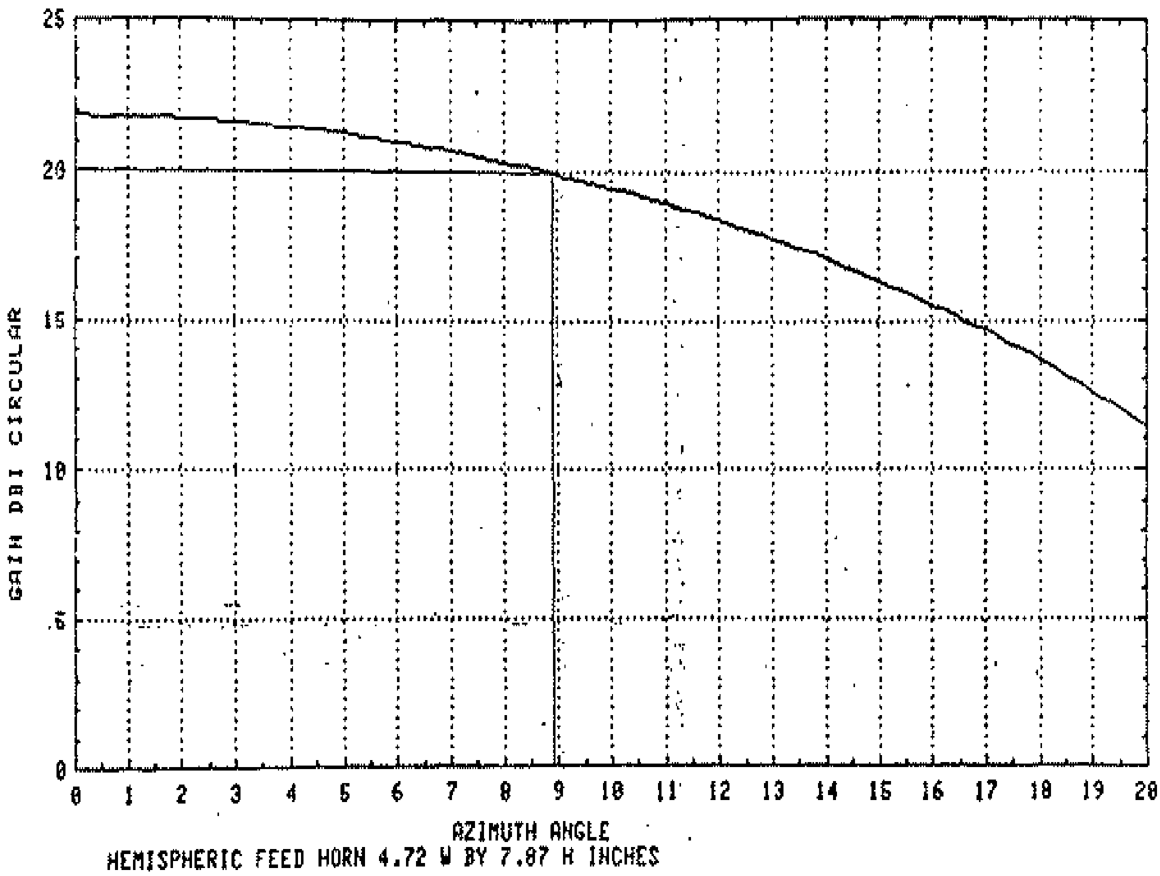


Figure 2.3-22. Hemispherical Coverage Horn - Azimuth Pattern to 20^0

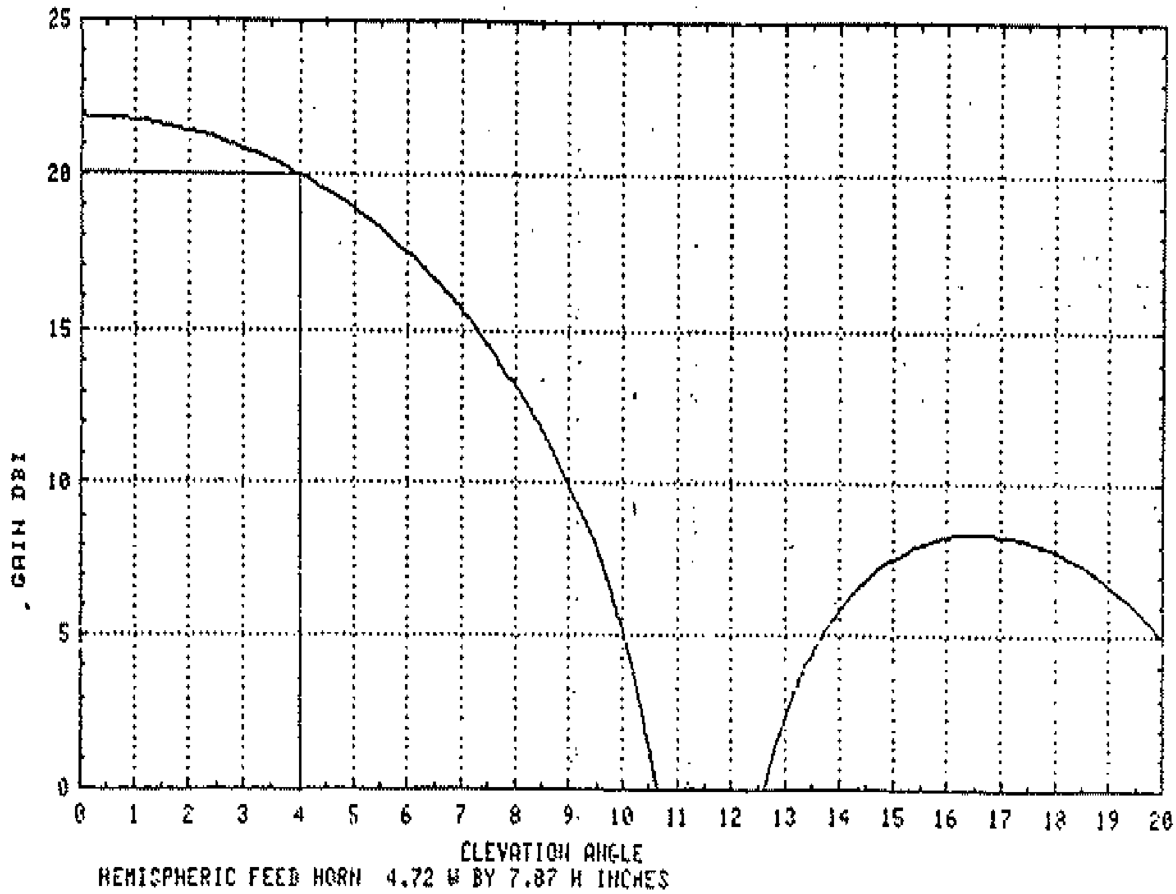


Figure 2.3-23. Hemispherical Coverage Horn - Elevation Pattern to 20^{0}

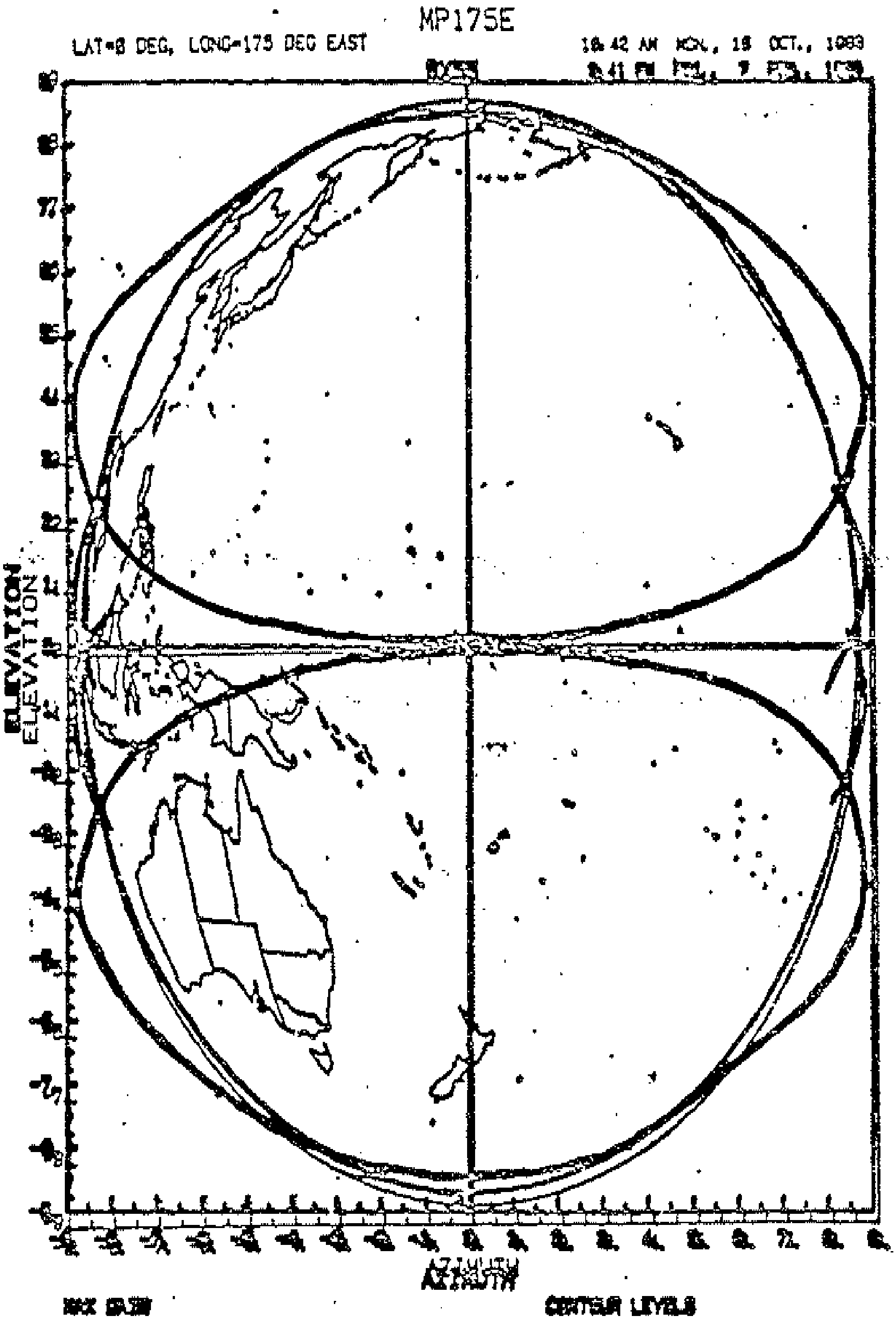


Figure 2.3-24. Approximate Coverages - Two Positions of Hemispherical Coverage Horn

Table 2.3-2. Hemispherical Coverage Horn

Weight Summary

	DSCS Part Number	Weight (lbs)
Horn Assembly		2.1
Actuator Drive Assembly (Incl. Harness)	47E237232	5.24
Rotary Joint	47D237240	.68
Rotary Joint Bracket	47D246085	.07
Horn Mounting Plate		.15
Waveguide Assembly		.11
Actuator Support Assembly	47E246060	2.40
		10.75 lbs

current GDA gimbal and rotary joints to steer in the elevation plane with the azimuth equal to 0°. This option was ultimately not acceptable since, from Figure 2.3-1 and Figure 2.3-4, it can be seen that coverage is required simultaneously in the Northern and Southern Hemisphere. Two axis positioning could provide the necessary coverage, but at the expense of reliability compared to the selected design. Figures 2.3-25 and 2.3-26 show the configuration of the steerable horn and the weight summary is listed in Table 2.3-2.

2.3.6 SCHEDULE

The schedule for the development and test of an engineering model antenna is listed in Table 2.3-3. A total of 20 months will be required in order to complete all electrical and mechanical design of the feed and reflector, fabricate and test engineering models, prepare prime drawings, and to complete all system thermal, structural and mass studies. In order to characterize the feed horn performance, two complete design, fabrication and test iterations will be required.

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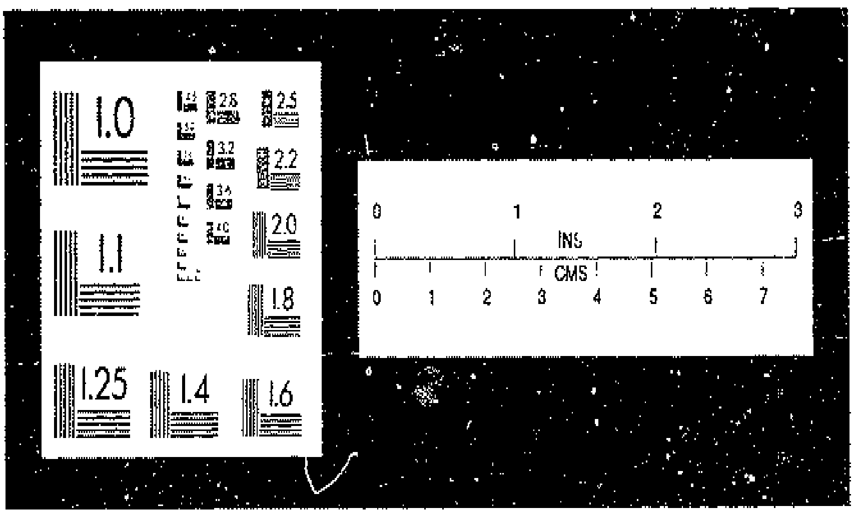

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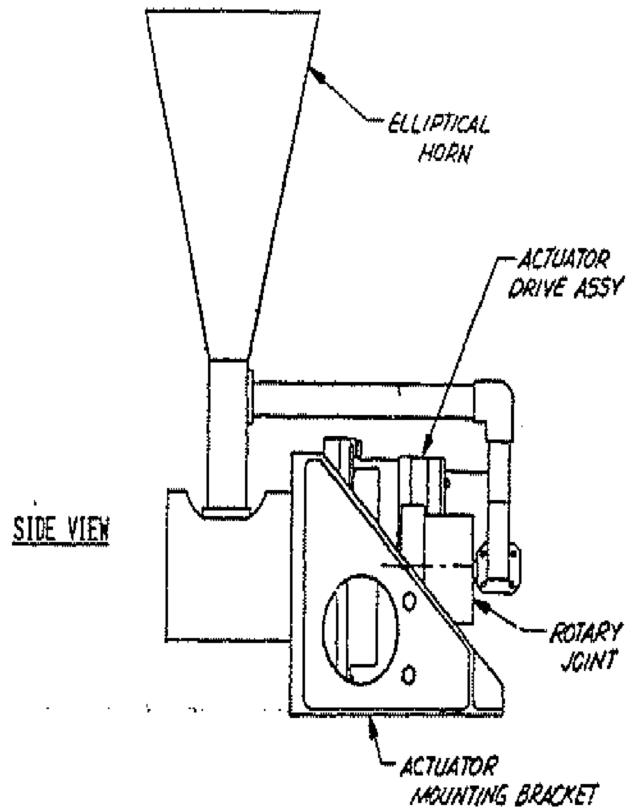


Figure 2.3-25. Steerable Hemisphere Coverage Horn

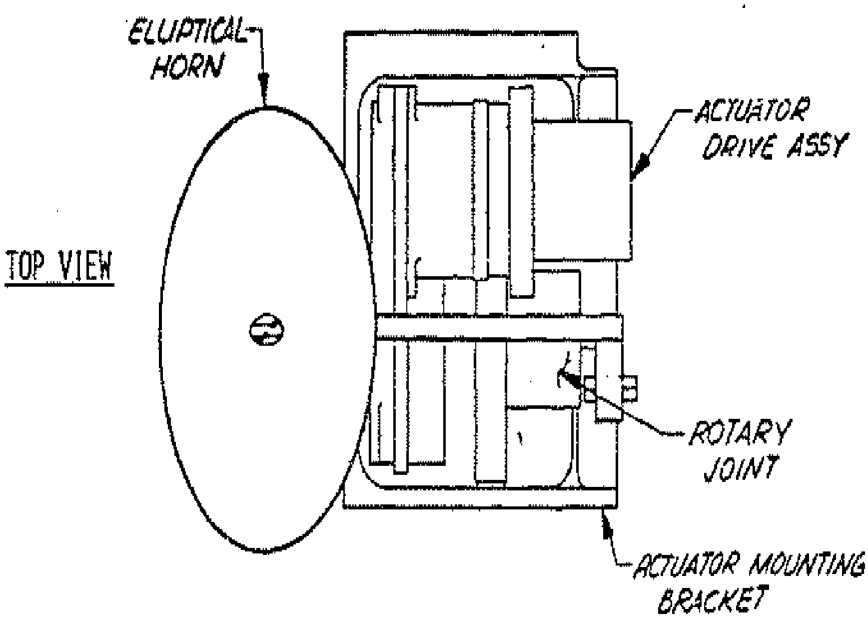
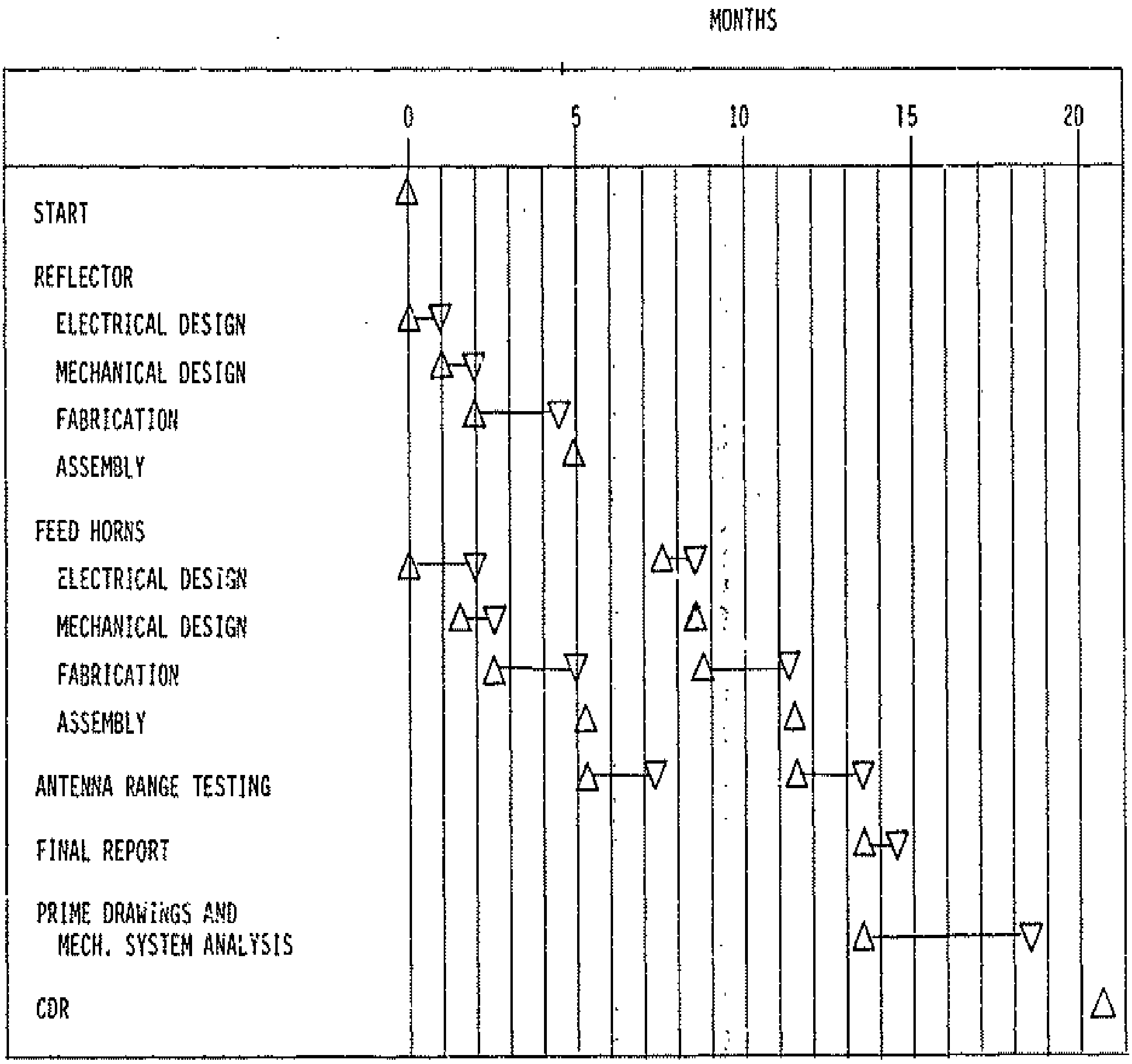


Figure 2.3-26. Steerable Hemisphere Coverage Horn

Table 2.3-3. Steerable Kidney Coverage Antenna Schedule



2.4 MIX REMOVAL WITH TWO GDA's, TWO TRANSMIT EARTH COVERAGE HORNS AND THE KIDNEY BEAM REFLECTOR WITH A 4 HORN FEED

2.4.1 DESCRIPTION OF SELECTED APPROACH

This is a combination of options A and B with the addition of a Kidney Beam Reflector with a 4 Horn feed (See Figure 2.4-1). The Kidney Beam reflector assembly is positioned in place of the MIX 19 MBA. This unit is much smaller than the 19 MBA and will fit comfortably in this position. The reflector will be structurally tied to the West Panel Honeycomb panel (Dwg No. 47J237 119) See Figures 2.4-1, 2.4-2, and 2.4-3. The Feed Horns will require structure built up from the West Panel Honeycomb structure to support the horn assembly.

The Kidney Beam Reflector with 4 Horn Feed will be insulated with multi-layer insulation blankets. Multi-layer insulation blankets will be redesigned in the area of the Kidney Beam Reflector because of removal of the 19 MBA assembly.

The new Kidney Beam Reflector assembly will require a complete qualification program using protoflight dynamic testing of the first flight article.

The build-up and testing of the Kidney Beam Reflector assembly will be handled in a similar fashion to the GDA assembly. Each unit will be tested as a separate sub-assembly and installed on the spacecraft at an appropriate time in the spacecraft assembly cycle following the modification kit scheme.

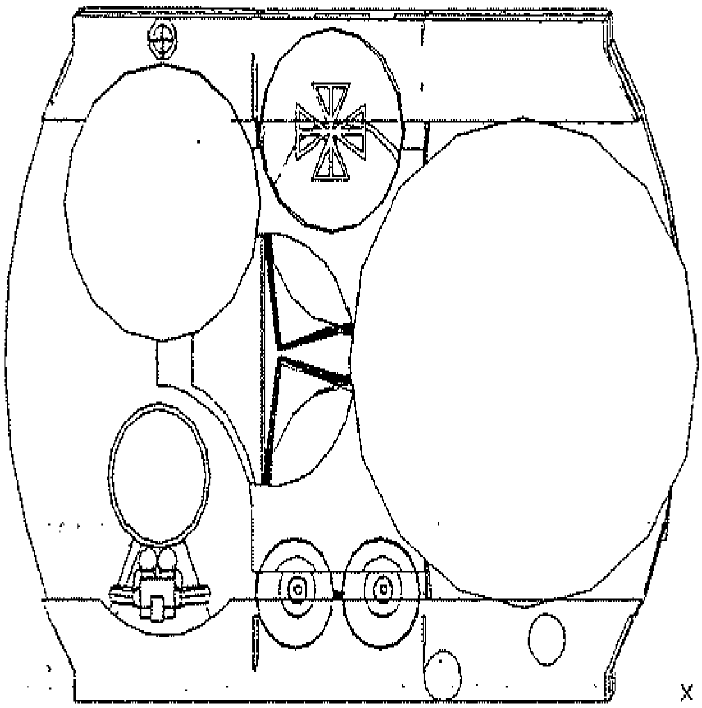


Figure 2.4-1. Top View Of DSCS Kidney Beam Antenna

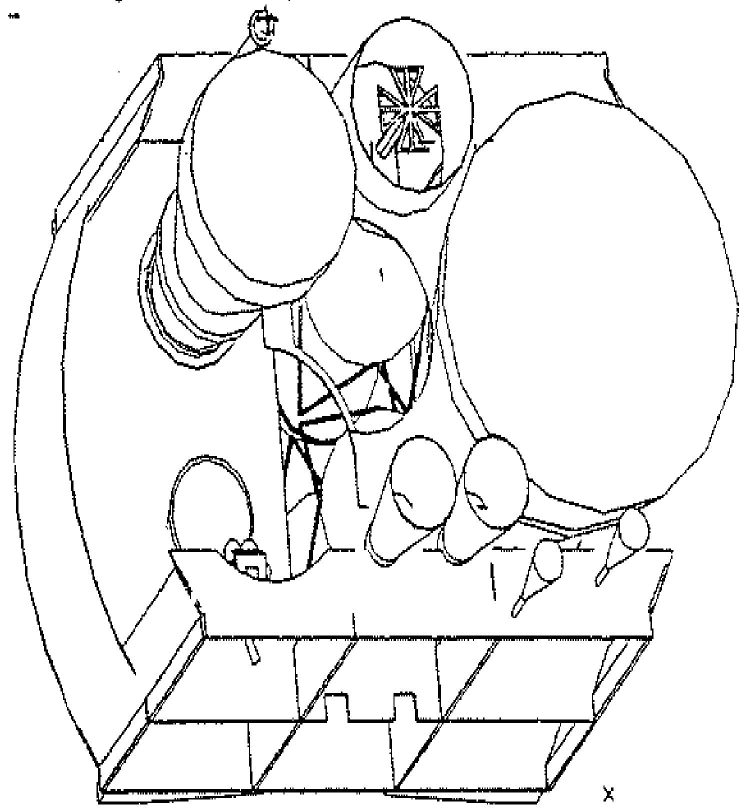


Figure 2.4-2. Three-Quarter View of DSCS Kidney Beam Antenna

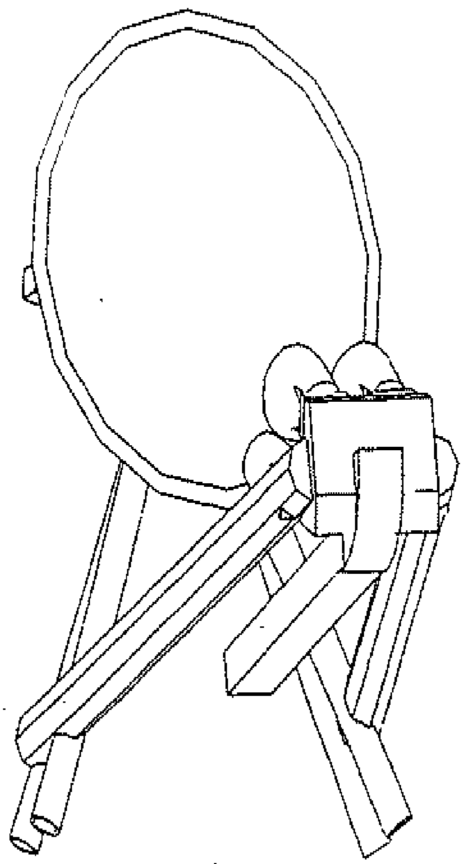


Figure 2.4-3. Kidney Beam Antenna with Fixed Feeds

2.5 ULTRALINEAR SOLID STATE AMPLIFIER FOR 10 WATT CHANNELS

2.5.1 PROGRAM DESCRIPTION

This section describes the development and implementation of improved solid-state power amplifiers which can provide a significant improvement in the communications capability of DSCS III 10 Watt Channels for the Multi-Year Procurement Program (MYP) vehicle production phase and beyond.

The amplifier design being proposed is based on the experience accumulated during B6/B7 10 Watt HESSA production and on new technology developed during the design and test of the 32 Watt HPSSA Engineering Model and implemented during the design and test of the 10 Watt B10 Breadboard Amplifier. Specifically the improved SSAs will provide:

1. Saturated output power capability of 16 Watts (42.05 dBm), an improvement of 2.5 dB over the current 10 Watt design.

2. Improved intermodulation product (IM) performance at back-off operation (39.7 dB) typical of IM performance at 5 Watts output on the current 10 Watt HESSA.

3. Commandable operation to limit RF output, and thereby DC power consumption, to 39.7 dBm/48.7 Watts for operation in jamming and overdrive conditions.

The amplifier implementation is herein referred to as the 16 W SSA, and is described in detail in the following sections.

The program to implement the 16 Watt SSA on the DSCS communications payload is based on a transition from the 10 Watt HESSA to the new amplifier starting with the B14 production vehicle or by retrofit onto earlier completed North Panels.

2.5.1.1 Amplifier Development Program

A significant amount of design definition and planning activity has already undertaken by General Electric - Space Division in support of the 16 Watt SSA program as part of the 10W HESSA (B10) and 32W HPSSA.

A portion of that activity has been involved with the evaluation of new FET types for a more efficient 10 Watt SSA, and the impacts of incorporating these devices into the HESSA design.

The design definition for a B10 10 Watt SSA amplifier has been completed to the point of assembling a complete high power segment into a breadboard HESSA chassis. That amplifier assembly in process is shown in Figure 2.5-1. Testing of the amplifier integrated with a prime power supply and low power is being completed as this report is being prepared.

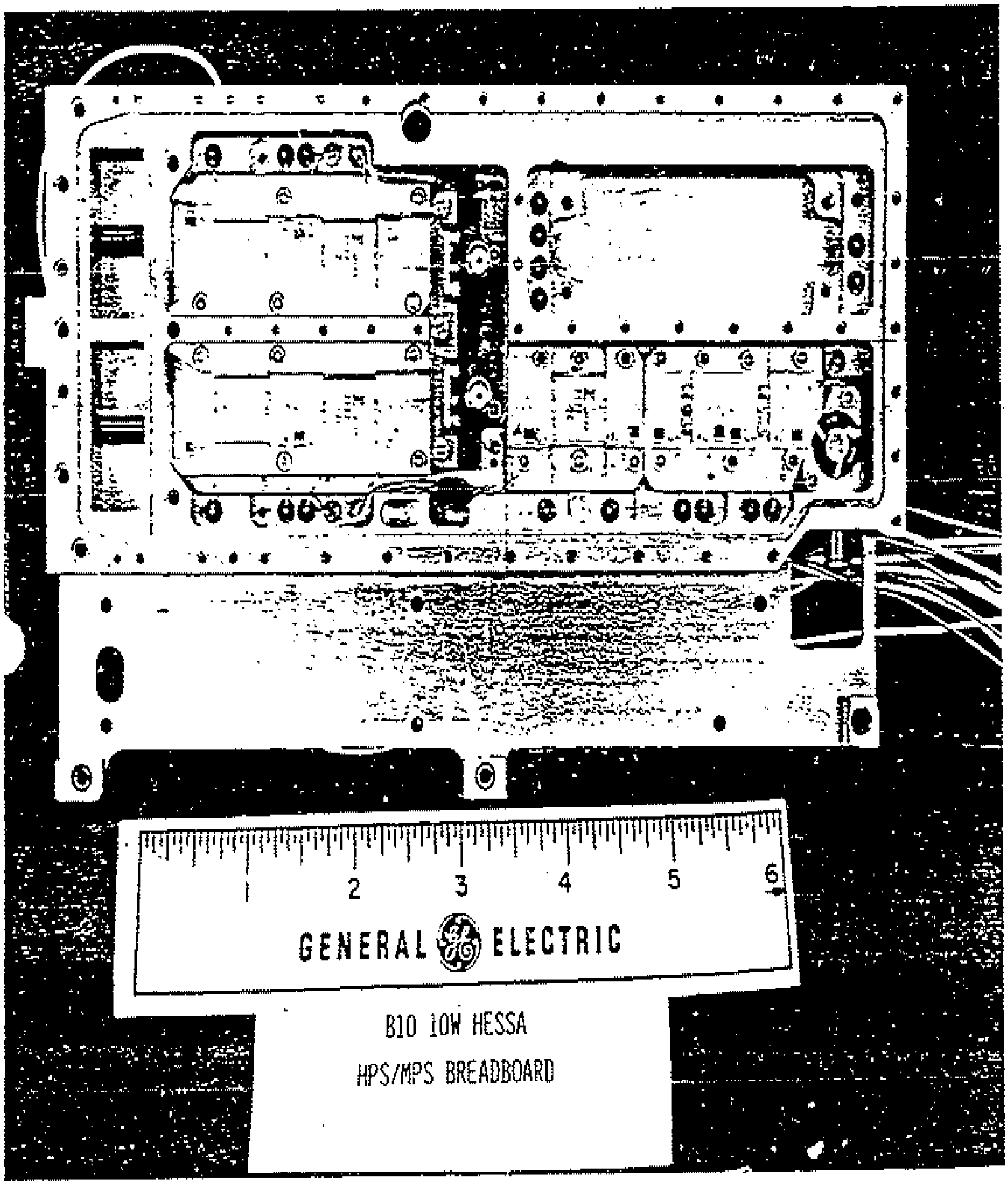


Figure 2.5-1. B10 10W HESSA HPS/MPS Breadboard

The significant design features of the B/B amplifier are the incorporation of a redesigned MPS assembly and HPS driver stage using new high efficiency FET devices developed in the 32 Watt HPSSA program.

The electrical performance of the breadboard will show improved RF bandwidth, lower DC consumption, higher PS reliability margin while preserving the improved linearity of GaAS FET amplifiers.

2.5.1.2 MYP Material Buy Program

The material required for the 16 Watt SSA is based on the design activity underway for the current HESSA baseline. With the exception of the new FET types required and parts required for the two hybrids/PWB's used in the design, all of the piece parts are in the current HESSA baseline MYP design.

The MYP material procurement in support of the MYP program has to date committed subcontracts for FET deliveries through the B14 vehicle. Thus, the transition to a new amplifier design will require negotiation and procurement of high efficiency, high power devices for the output devices.

2.5.2 AMPLIFIER DESCRIPTION

2.5.2.1 Design Approach

The design concepts proposed for the implementation of the 16 Watt Solid-State Amplifier (16 W SSA) are based to a great degree on the design and technology which has been demonstrated and proven in the 10 Watt production HESSAs for the DSCS III B4-B9 vehicles, and on some of the newer design features of the 10 Watt B10 HESSA resulting from the 32 Watt HPSSA development program recently completed.

The major addition to the baseline design information which is required for the successful development of the 16 W SSA is the design of a commandable attenuator network which will permit operation of the 16 W SSA in various modes as required to allow control of maximum power consumption of the unit as a function of operating conditions and vehicle power system capability.

The only other modification in component design from the 10 Watt B10 HESSA baseline is the use of a new family of Gallium Arsenide FETs. These devices were tested in the 32 Watt HPSSA design and are qualified by the supplier under GE subcontract. The prime procurement specification for the family was approved by the DSCS PMPCB and are being procured for the B10-B14 vehicles. Availability of devices for the 16 W SSA implementation is not a high risk, based on the current status of FET development, testing and shipment.

2.5.2.2 Design Objective

Output Power Performance

The design objective of the amplifier development include the ability to provide the 16 Watts (42.05 dBm) of output power at 5 dB compression from linear gain. This is called saturated output power even though technically the amplifier could deliver more power with higher drive.

This will assure that small-signal gain requirements will be met and that adequate input drive level back-off occurs when operating under linear conditions typical of FDMA communications. This will insure high-linearity (<-25 dBc 3IM products) at carrier levels of 37 dBm (5 Watts), and provide 3 dB of increased channel capacity for users.

At the same time, the amplifier must be able to operate within the constraints imposed on it by the satellite electrical and thermal subsystems, and without impacting communications subsystem performance. The efficiency and flexibility of this amplifier is key to meeting these requirements.

The high-efficiency characteristics of the specified FET devices will allow linear operation of the amplifier at output levels up to 39.7 dBm (linear) within the DC power budget of the current 10 Watt HESSA at saturation (48.7W), while providing IM performance typical of HESSA 3 dB back-off operation.

Operation of the amplifier at more than 39.7 dBm of output power (under increased drive conditions) causes DC power consumption to increase above 48.7 Watts. This condition may or may not be acceptable at that time to the vehicle electrical power subsystem and the thermal control system, depending on the loading of other comm channels and use of other subsystems, or the condition of the battery/solar array system as it is affected by mission duration, eclipses, failures, etc.

To prevent over-consumption or thermal dissipation problems under conditions such as the amplifier being driven by a jammer or other input source <u>when not desired</u>, the amplifier circuity will include switchable attenuators which can be controlled via DC power sensors and/or by ground command to reduce amplifier gain, output power (saturated), and thereby DC power consumption.

The currently proposed power transfer function options will provide typical saturated performance as listed in Table 2.5-1.

Table 2.5-1. Attenuator Limited Maximum Output SSA Performance

Output Power (watts)	Output Power (dBm)	Switched Atten. Reqd. (dB)	DC Power Consumption (watts)	DC Power Dissipation (watts)	Application
16	42.05	0	TBD	TBD	Saturated Operation (SSMA, TDMA)
~10	~40		48.7	38.7	Linear Operation (FDMA)
10	40	7.55	48.7	38.7	Saturated Operation (SSMA, TDMA)

2.5.2.3 Design Description

The 16 W SSA has as design requirements, besides the electrical performance requirements summarized in Paragraph 2.2, the need for total mechanical interchangeability with the 10 Watt HESSA at North Panel assembly. This constraint is considered mandatory as a result of the requirement not to impact North Panel mechanical design for this upgrade. An assessment of component and device performance capabilities concludes that the current HESSA mechanical interface will meet the packaging requirements for the 16 W SSA and only minor internal mechanical changes are required. The major subassemblies of the HESSA design, i.e., the Power Supply, Low Power Segment, and High Power Segment will be retained as they currently exist, and will be modified only to incorporate the attenuator networks and control electronics changes described herein.

The performance characteristics will be defined in a new specification which will be similar to SVS-10748, the HESSA specification. All major performance characteristics will be maintained as is, except for those directly affected by the increase in power; such as DC power consumption, dissipation at saturation, acceptance temperature range increase, gain characteristics for the switchable attenuator settings, and the addition of performance definition for the additional control electronics. Based on actual weights of 10 Watt HESSAs and the estimated complexity of the attenuator electronics, no increase in the SSA weight specification is anticipated.

The HESSA electrical interface, i.e., power, command, and telemetry, will also be maintained for the 16 W SSA, except for replacement of the current analog telemetries with other functions determined to be more relevant to SSA performance monitoring, and the addition of four command inputs for attenuator control on spare connector pins. Adequate capacity exists in the IFU/RTU systems to accommodate the added lines required, and no change in HESSA connector types is required.

2.5.2.3.1 Low Power Segment

The 16 W SSA Low Power Segment will retain the mechanical and electrical design features of the LPS from the 10 Watt HESSA, except as follows:

1. The current temperature compensation PWB used in the LPS will be deleted. This feature will be packaged in the mode control hybrid which will be installed in the cavity on the ctherside from the LPS balanced amplifier.

2. The PWB cavity will be modified to package the switched attenuator network RF circuits and control electronics. The mode control hybrid will be designed for the electronics and will be mounted in the attenuator section.

3. The RF amplifier section will be modified only with the addition of one additional Pin Diode Attenuator module (of the current design). The HESSA LPS mechanical design will be modified to provide the required room for these modifications.

The switchable attenuators to be added to the LPS circuitry consist of RF hybrids, with an attenuator in one branch and a low-loss 50 ohm line in the other branch.

Attenuation selection is provided by biasing PIN diodes so as to have zero or finite attenuation in series with the transmission line.

Four diodes may be used, operated off a single command line. Polarity of the diodes will be established such that a positive control voltage will insert the 50 ohm line into the path, and a negative control voltage will insert the attenuator element into the RF path. Bias resistors in series with each diode will control drive current to achieve diode impedance levels and balanced current distribution as required to operate the switch.

2.5.2.3.2 Medium/High Power Segment

The 16 W SSA Medium/High Power Segment assembly will retain the mechanical and electrical features of the B10 HESSA design, which uses the module design concept proven in the 32 W HPSSA program (see Figure 2.5-2).

The MPS design will continue to consist of an input isolator assembly, and a MPS amplifier of a three-stage design. The carriers will mechanically be interchangeable with the HESSA MPS modules. The chassis provides individual gate and drain bias feedthroughs for added flexibility during module level tuning.

The two way divider assembly will be retained, as designed for the HESSA.

The HPS amplifier modules will be similar to the HESSA modules but will mount the power FETS directly into the chassis for improved thermal characteristics. Only internal chassis modifications will be required to accommodate this modification. Tuning of HPS circuitry will occur in the assembly. Better matching can be accomplished by tuning the modules into the exact operating impedances, thereby improving the performance of these stages relative to bandwidth and efficiency. A cross-section of the HPS with soldered-in FET packages for low thermal impedance is shown in Figure 2.5-2.

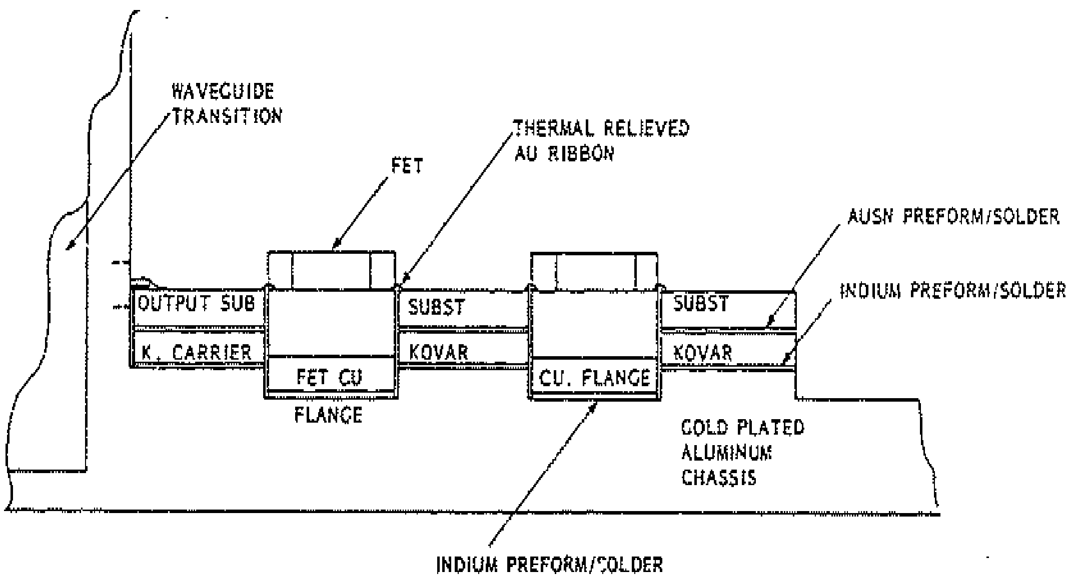


Figure 2.5-2. High Power Amplifier Assembly with Power GaAs FETS Soldered Directly to Chassis for Minimum Thermal Impedance

2.5.2.3.3 Combiner

The 16 W SSA combiner subassembly will be electrically identical to the HESSA combiner. All MYP procured combiners have been analyzed for power handling capability, thermal considerations of at least 20 watts. Based on available data on the existing combiner, no redesign or reprocurement will be necessary.

2.5.2.3.4 Mode Switching

Three operational modes are implemented using switchable attenuators, a control hybrid, and the input current sensor shown in Figure 2.5-3. Appropriate attenuation is automatically switched in to limit the HPS amplifier drive and power consumption if the current sensor threshold is exceeded. The threshold corresponds to 48.7 Watts of DC power. Automatic attenuator switching may be disabled by the ground command. The first two non-power limited modes can provide 10, linear, or 16 Watts fixed saturated output power are used for ground test and during operation in orbit when the spacecraft has the power capacity to support 10 or 16 watt operation.

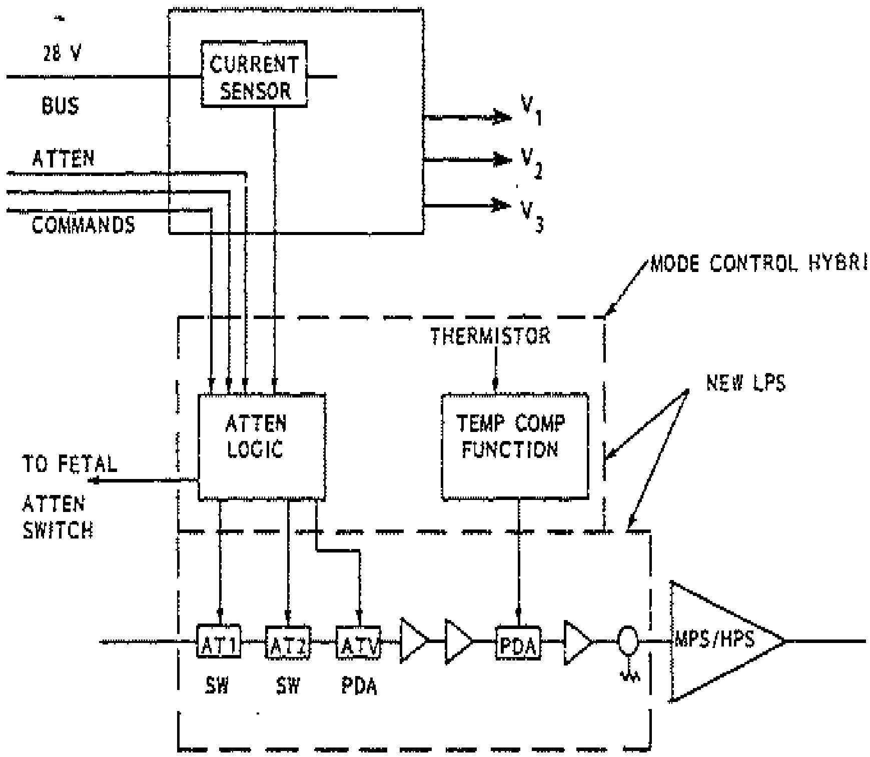


Figure 2.5-3. Mode Control Block Diagram

For FDMA operation, the SSA is a 16 Watt amplifier operated backed off to provide 10 watts linear. For SSMA or saturated operation, the SSA is a 16 Watt unit in early satellite life, and a 10 Watt unit later unless additional power capacity is available.

2.5.2.3.5 Mode Control Hybrid Design

The 16 Watt SSA RF design implementation is based on the use of a hybrid circuit to provide temperature compensation and mode selection control.

Control of the modes of the 16 Watt SSA as described in previous sections require control of a variable PIN diode attenuator and two switching attenuators. Two levels of operation are planned for the amplifier as listed in Table 2.5-2. The first level is as a 16 watt amplifier. The second level of operation is as a 16 watt backed off amplifieer or a 10 watt saturated amplifier automatically switched using a current sensor and a smaller switched attenuator.

Commands for SSA mode control will consist of three inputs; the existing pulsed latched-relay commands available at each channel for TWTA self-protect circuit operation, and two additional logic-type bilevel commands to be added to the IFU outputs.

Table 2.5-2. 16 W SSA Operating Modes

COMMAND	FUNCTION	LINEAR MODE	SAT. MODE
LEVEL 1	RESET LATCHING RELAY AND DISABLE SWITCH DRIVER	< 48.7 Watts D.C.	16 Watts R.F. ~61 Watts DC
LEVEL 2	RESET LATCHING RELAY AND ENABLE SWITCH DRIVER	< 48.7 Watts D.C.	10 Watts RF < 48.7 Watts D.C.

A block diagram of the attenuator logic circuitry is shown in Figure 2.5-4. The decoder block diagram is shown in Figure 2.5-5.

Operation of the circuit is described as follows:

The commands are processed by the logic controller to determine the selected mode. If the selected mode is a fixed (non-automatic switching) output level mode, the logic levels to the enable/set blocks are preset to shut off the PDA and command attenuators 1 and 2 to the required level regardless of the output of the bus current monitor/latch. If the selected mode is an automatic switched mode the latch is reset and the gain and threshold of the bus current monitor is established to provide a logic transition at the select power consumption level. The set/enable blocks are simultaneously set to allow a detected threshold to switch the required attenuator(s) into the RF circuits. The attenuators will remain set due to action of the latch circuit after the power consumption has been reduced.

RF operating points on a power transfer curve are shown in Figure 2.5-6.

2.5.2.3.6 Power Supply

The Ultralinear Solid State Amplifier requires for its automatic, power limiting, switching modes a current sensor that will sense the presence of excess DC current (or power). The sensor will be situated in the power supply and will send a command to the logic to switch to a lower power consumption mode.

The power supply overall design needs to be evaluated for load power handling capability. The increased load capability of approximately 50% may induce high stresses in piece parts that would decrease their reliability. Changes to the design are then appropriate. The schedule for Ultralinear Solid State Amplifier is shown in Figure 2.5-7.

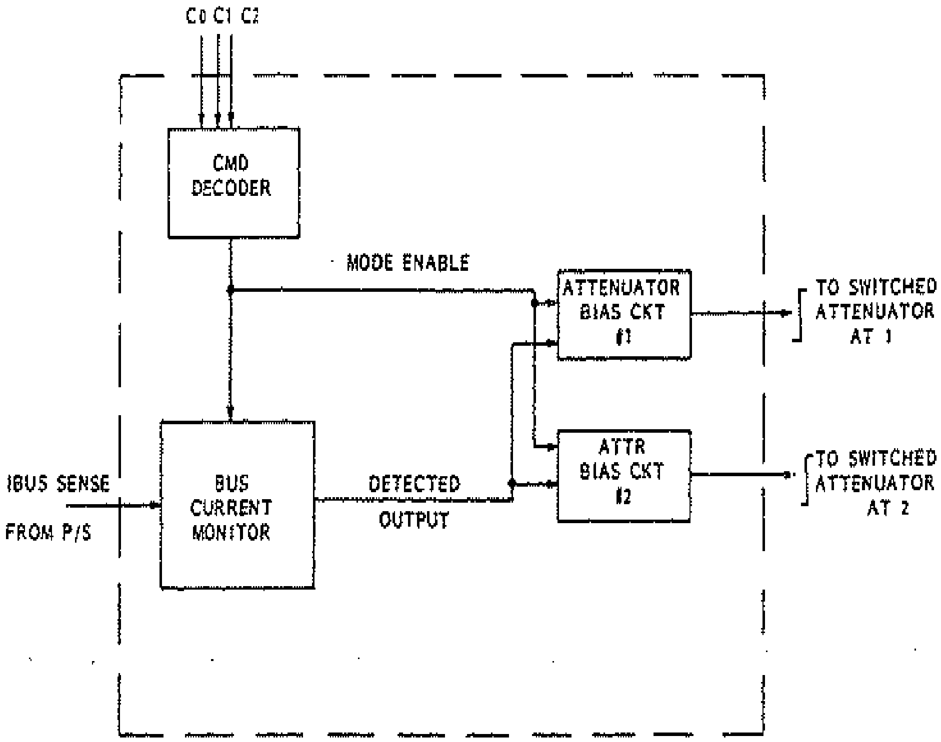


Figure 2.5-4. SSA Attenuator Logic Block Diagram

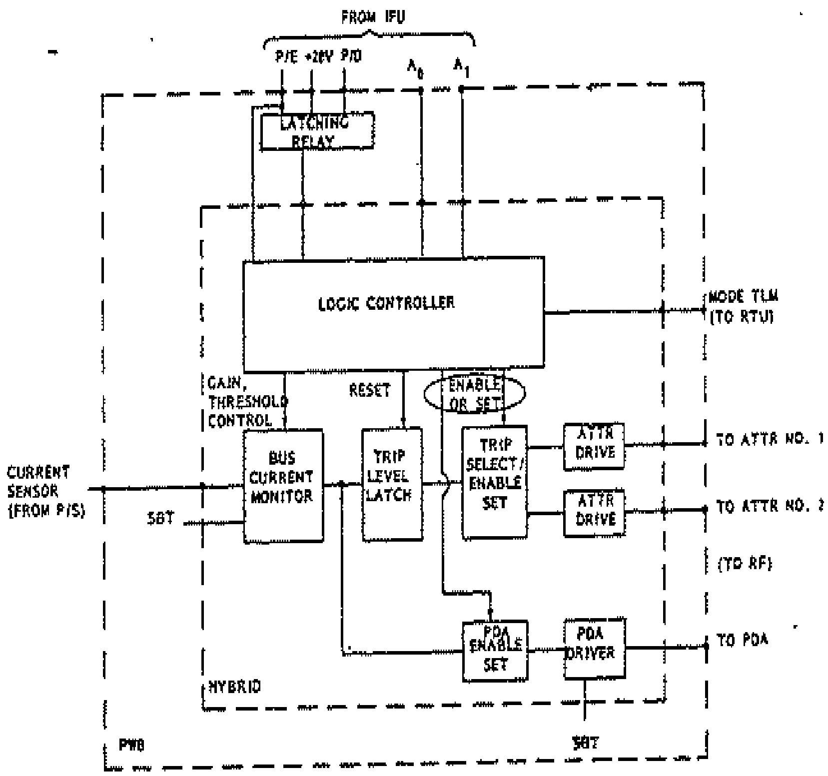


Figure 2.5-5. Decoder Block Diagram

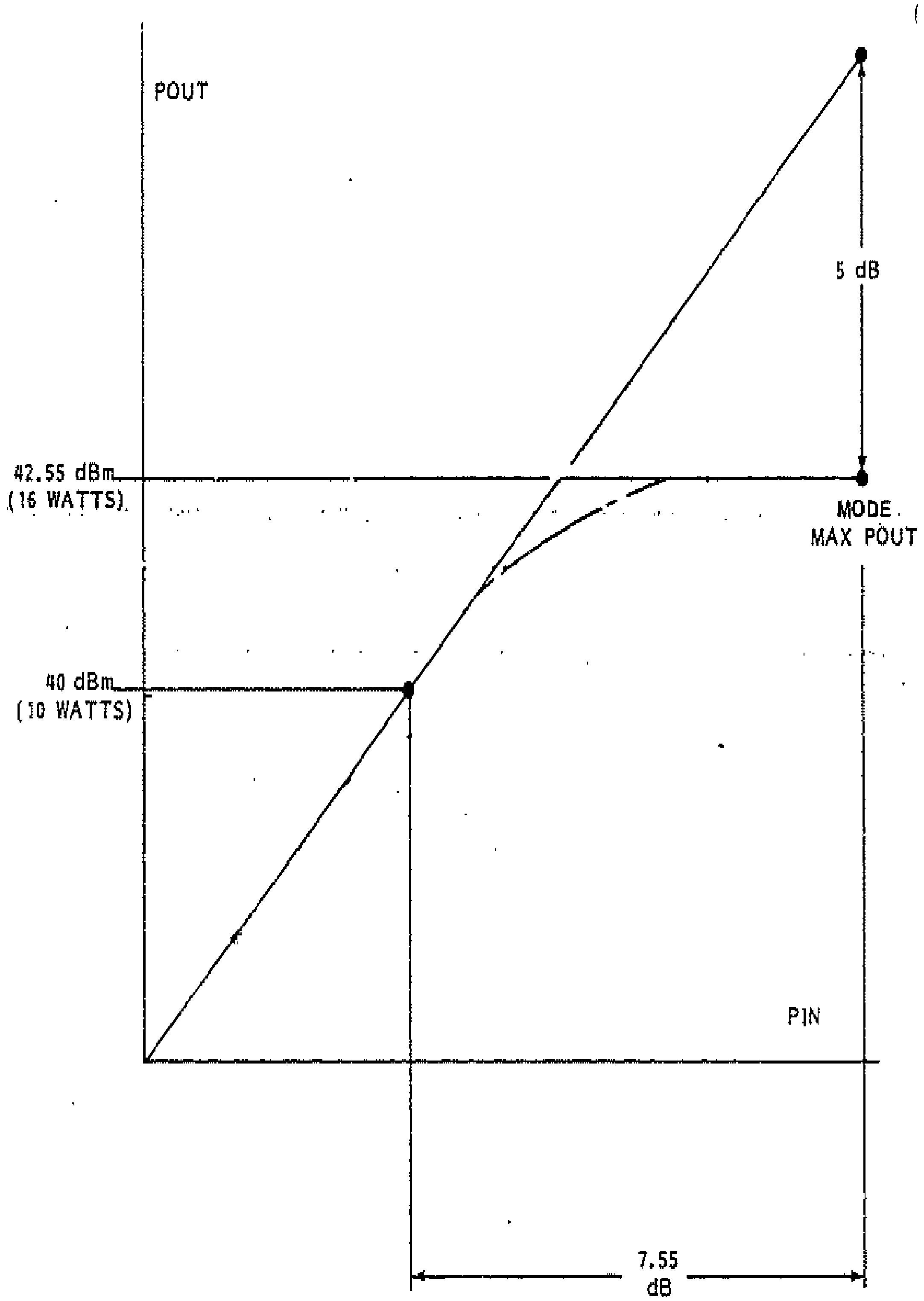


Figure 2.5-6. ULSSA Operating Points

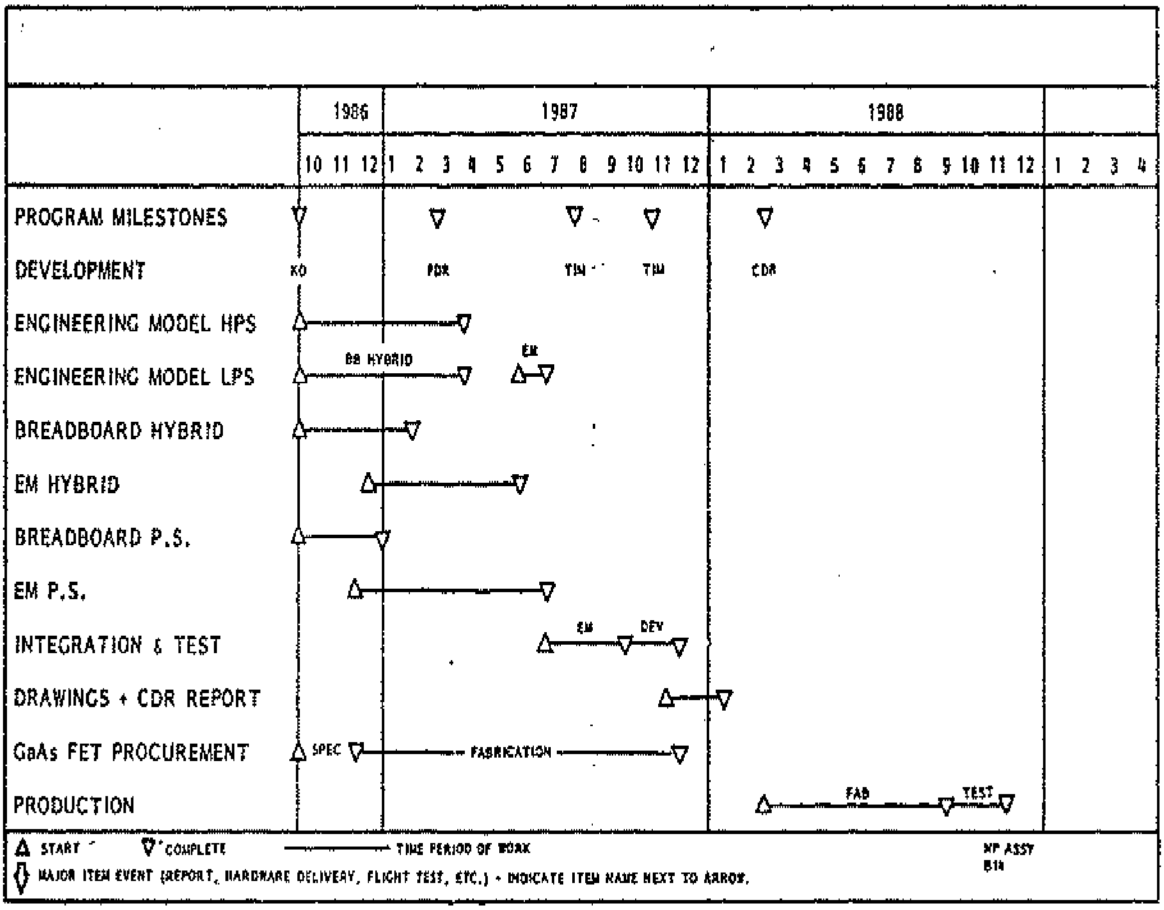


Figure 2.5-7. Schedule for Ultralinear Solid State Amplifier

2.5.3 SYSTEM IMPACT

Incorporation of this power amplifier in place of the 10 Watt HESSA on the MYP DSCS III spacecraft has minimal spacecraft impact, and accordingly, minimum overall program risk. Specifically, the power amplifier will be designed to require no modifications to the present spacecraft structural, power, or thermal designs. The mounting footprint (including connector locations) are identical to the present 10 W HESSA. No power subsystem design changes are required to operate the proposed power amplifier in the linear (10 Watt) mode throughout the entire mission or in higher power saturated modes during early mission phases when excess spacecraft power is normally off-loaded through the shunt dissipators. Operation of the amplifier in the 16 watt saturated mode results in approximately TBD Watts of additional heat dissipation by each unit (TBD Watts for four units in channels 3, 4, 5, and 6) results in a maximum baseplate temperature of approximately TBD degrees Centigrade. Linear (10 Watt) operation of the amplifier results in the same power dissipation as the HESSA, and has no impact at all on spacecraft thermal performance.

Commands- and telemetry for the power amplifier modes require minor modifications to the spacecraft electrical wiring and interface signal conditioning in the north panel IFU/RTU. The modifications entail additional harness wires to route commands from the IFU to the individual power amplifiers and to route telemetry signals back to existing telemetry channels in the CTU. IFU modifications are limited to wiring additions and replacement of a telemetry/command signal processing board in an existing IFU PWB slot. Requalification or flight proofing (protoflight) of the IFU would not be required based on the proposed modification.

2.5.4 RISKS OF SELECTED APPROACH

Development

The development risks are moderate since the amplifier is similar to the B10 HESSA. Specifications in RF saturated performance is intimately related to the FET specifications. Specifications for multiple operating modes need to

be worked. GE is confident that Fujitsu can meet the stringent FET specs. The HPS hardware design poses no risk. The risk to the development of the control hybrid is a schedule risk. The remaining LPS hardware design poses no risk.

Production Risks

The amplifier is slightly more complex than the B10 HESSA because of the multiple operating modes. Tuning and testing times need to be increased 20%. Hybrid fabrication time is significant and will impact the lead time required.

2.5.5 RATIONALE FOR SELECTED APPROACH

The 16 W SSA approach is one method of increasing intermodulation performance. Another method, the linearization of a power transmitter by predistortion, is being considered as a separate approach of this special study. It is likely that a combination of both techniques in a single transmit channel will give best results.

Other FET arrangements within the High Power Segment were considered. These could be slightly more efficient (1 Watt savings per amplifier) but would require a significantly more redesign of the RF high power segment and modules. The approach was therefore discarded.

2.5.6 ACTIVITY REQUIRED TO IMPLEMENT 16 W SSA ON FINISHED SPACECRAFT

To retrofit a 10 W HESSA, North Panel disassembly would be necessary. The 10 Watt HESSA would then be removed. The 16 Watt Solid State Amplifier could be mounted in the same space with the same screw holes. The RF input cable and RF output waveguide location is the same. The DC input cable and IFU will have to be replaced to ones where the automatic switching can be activated. The survivability shields on the underside of the North Panel may require adjustment in the area of the output HPS FETs. The thermal blankets will need to be opened to provide maximum cooling. North Panel and Spacecraft Level retests would thus be required.

2.6 SHF LINEARIZER DEVICE

2.6.1 PROGRAM DESCRIPTION

This section describes the development and implementation of a Linearizer which can provide a significant improvement in the communications capability of DSCS III transmit channels 1 through 6, 40 and 10 Watt levels, for selected Multi-year Procurement Plan (MYP) and future vehicles.

The Linearizer design being proposed is based on technology developed in GE IR&D programs and recent experimental measurements.

Specifically, the Linearizer will provide more linear channel power than possible in present SHF communications channels. The principal measure of this capability is in improved intermodulation performance at the output power levels at which the channel is expected to be used. For DSCS III 10 Watt channels improved IMD at a power level 3 dB less than saturated power is highly desirable even with no further improvement at the saturated power level.

The proposed Linearizer implementation is described in detail in the following sections of this proposal.

The implementation is planned in three steps, as follows:

1.	Linearizer Development	(Non-Recurring Engineering)
2.	Long-Lead Parts Procurement	(Dual-Gate GaAs FET)
3.	MYP Implementation	(Production)

2.6.1.1 Development Program

A significant amount of design definition has already been undertaken by General Electric - Space Division in support of the Linearizer development.

A portion of that effort has been involved with the fabrication and assembly of a "breadboard unit", preliminary tuning and testing with several types of transmit amplifiers. FETs from two sources have been considered.

The significant design feature of the Linearizer is the use of dual gate FETs with in phase and quadrature hybrids to achieve gain transfer characteristics which are complementary to that of the transmit amplifier. Additional small signal gain stages are required to make up for gain loss in the dual gate FETs.

The electrical performance of the Linearizer coupled to transmit amplifiers is expected to show better IMD performance at the P_{sat} -3 dB and P_{sat} -6 dB points. Ranges of improvements are dependent partially on type of transmitter (TWTA or SSA).

2.6.1.2 Material Buy Requirements

The material required for the Linearizer is based on that which is currently used in the HESSA and other Microwave Integrated Circuits components in production for the DSCS III MYP program. The only exception is the new Dual Gate FET required. Additional quantities of presently used parts which are a part of the DSCS III EEE approved parts list are required.

Assuming an October 1986 initiation date, a parts procurement document needs to be drawn and negotiated with the FET supplier. A 12 month procurement cycle for these devices was estimated by a potential supplier. This time appears to be realistic based on procurement cycles which have been met by suppliers for both low noise and power GaAs FETs for the HESSA program in previous procurements. The overall Linearizer schedule will be the same as that shown for the Ultralinear HESSA.

2.6.1.3 Production Program Impact

The designs of the Linearizer modules are similar to present low power segment modules used in the HESSA program. A chassis would be designed to house the several amplifier modules which make up the Linearizer. No new productions or test techniques or test instrumentation is required for this component.

Preliminary comparisons of the designs conclude that the complexity of the Linearizer is similar to the Low Power Segment of the HESSA. Because of the impact of transitioning to a subsystem that includes the Linearizer will require only a conditioning period to become accustomed to working with a new component and inclusion of an additional alignment step.

2.6.2 DESCRIPTION OF SELECTED APPROACH

The Linearizer is a predistortion device placed at the input to the power transmitter. It uses dual gate, small signal FETs as the predistortion elements. The Breadboard Linearizer is shown in Figure 2.6-1. The signal is processed through a 3 dB lange coupler and two symmetrically located dual gate GaAs FETs. The output is recombined in an in-phase 3 dB hybrid. The size and complexity is about that of a low power segment module shown in Figure 2.6-2. Two additional low power segment modules are used in the Linearizer to make up the gain loss of the dual gate stage. An output isolator provides added isolation to interface cables and transmitter input mismatches that may be present. The three active modules require two regulated voltages to operate. The +5V line will apply to the two dual gate and four single gate drains. The negative voltage will apply to the four gates or the two dual gate FETs. To provide these voltages positive and negative voltage regulators circuits will be part of a printed wiring board in an adjacent cavity. The regulators will be sequenced such that the positive voltage is applied after the negative voltage has been established. Figure 2.6-3 is a schematic for a regulated sequence turn-on circuit that might be used.

The Linearizer will consist of the following piece parts:

Balance Amplifier Modules	2
Dual Gate FET Module	1
Output Isolator Module	1
Chassis	1
SMA-F Connectors	2
PWB Assembly	1
Cover	1
Feedthrough Filters	2
SBT Attenuator (Coaxial)	1

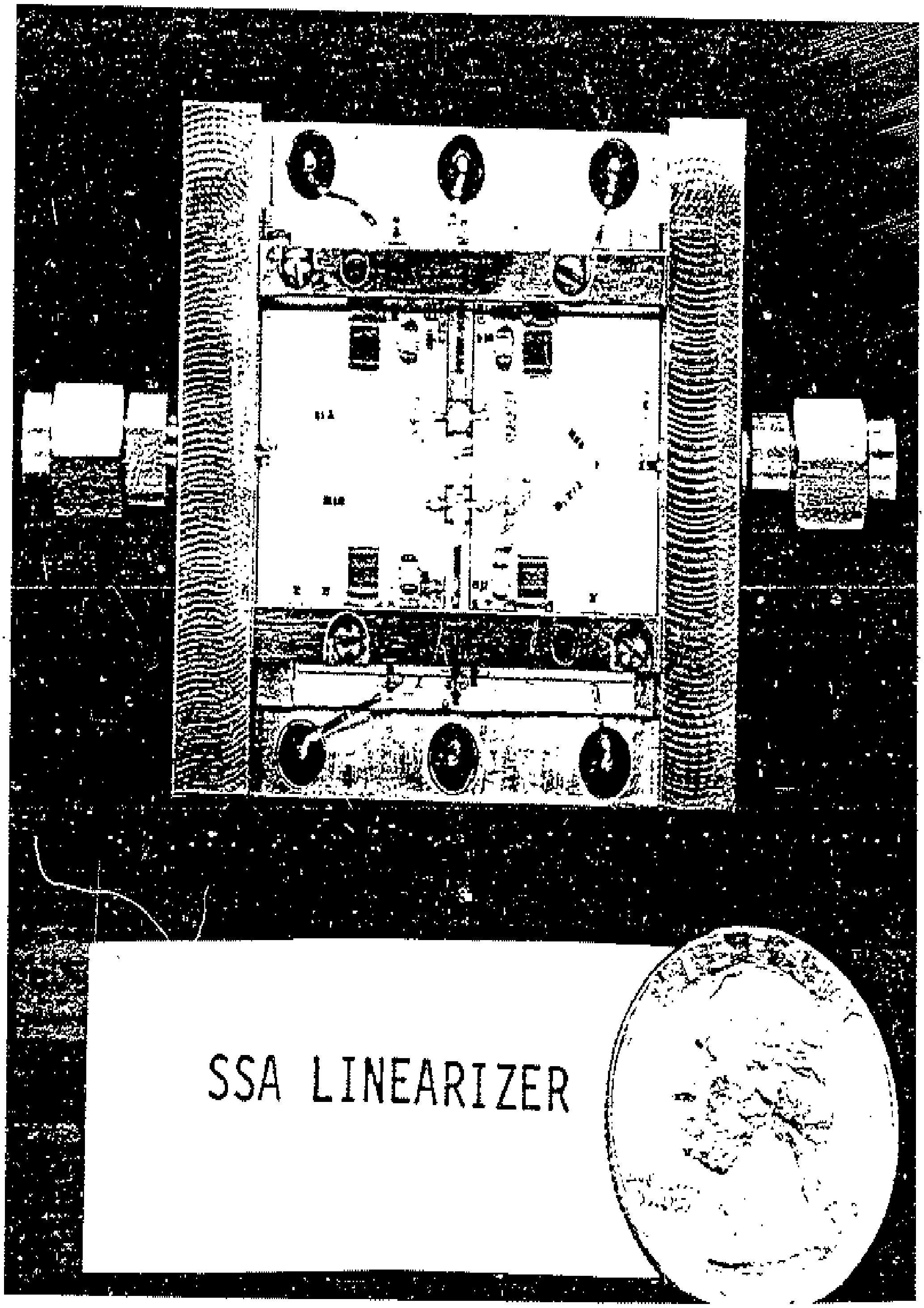


Figure 2.6-1. SSA Linearizer

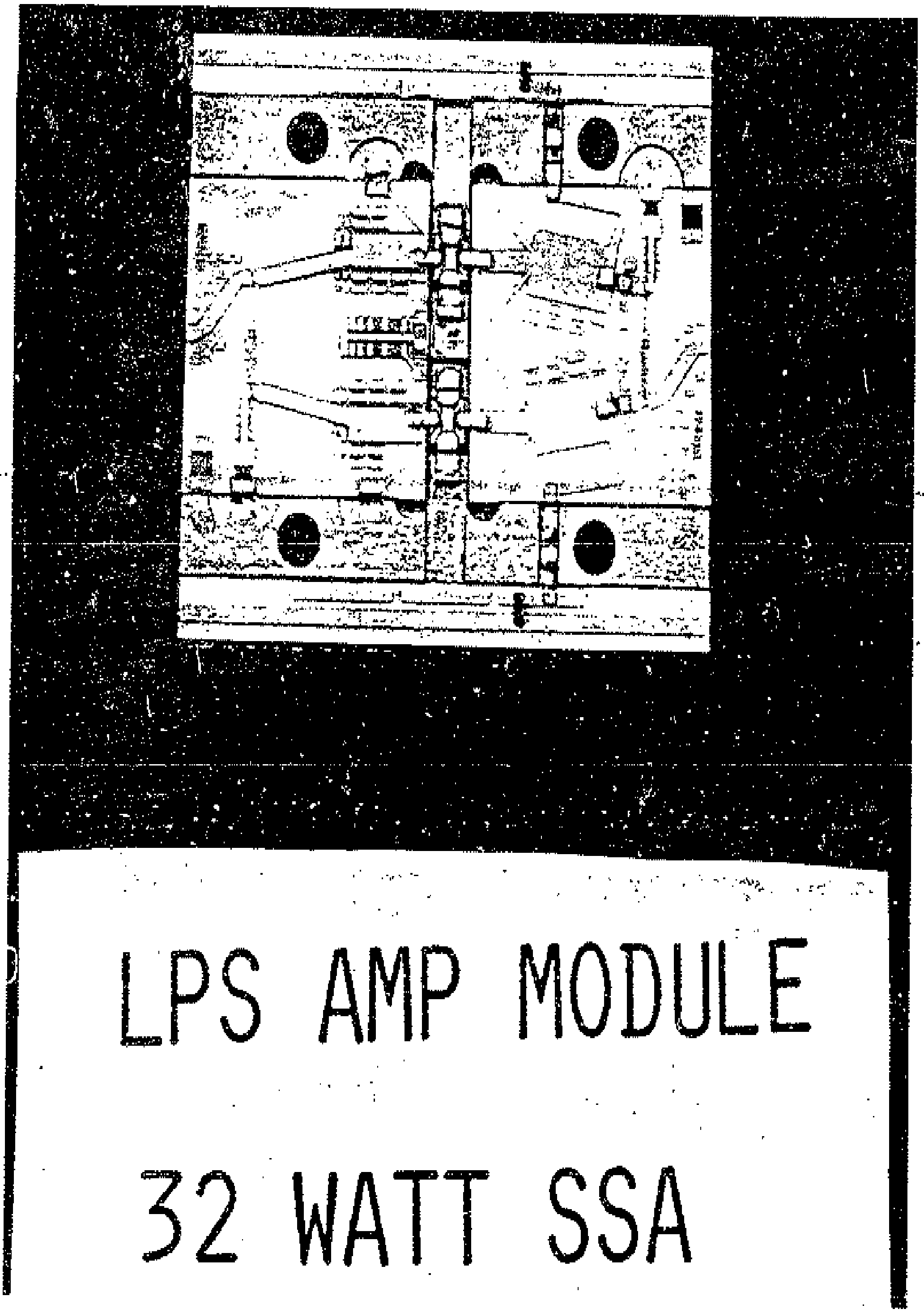


Figure 2.6-2. LPS Amp Module

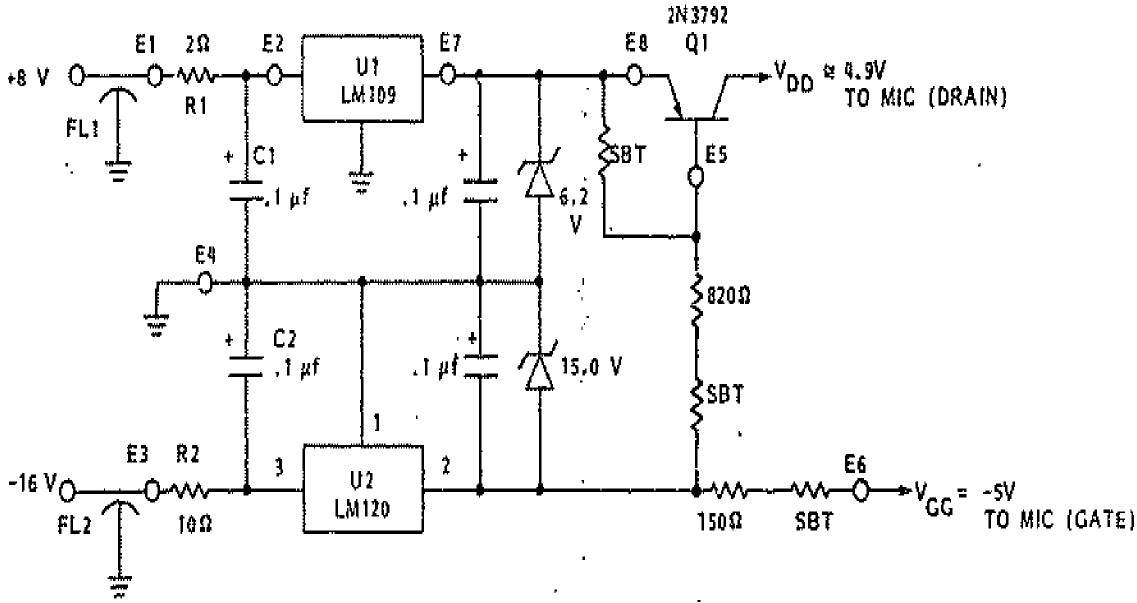


Figure 2.6-3. Linearizer Regulator/Sequencing Circuit

The overall complexity of the Linearizer is comparable to the low power segment of the HESSA. Figure 2.6-4 shows how the Linearizer would appear.

2.6.3 PERFORMANCE ESTIMATES

Since the Linearizer is a new component it will require a new specification be generated. The principal merit of the component is to be able to linearize the transmit amplifier which follows it. The performance of the Linearizer and amplifier will be specified and tested at a high level assembly. Its combined performance will not be specified here. The performance is strongly dependent on the type of transmit amplifier, TWTA or HESSA and its specific performance.

The key performance parameters that the Linearizer will have to meet are addressed in this section.

1. <u>Frequency Response</u> - The Linearizer is principally a small signal amplifier with a pronounced gain expansion of about 5 dB maximum. Because it is in the small signal portion of the transponder chain its bandwidth must be sufficiently wide to not significantly contribute to the channel response. To ensure this case the Linearizer may operate over 3 bands which cover the 6 channels. Therefore G1 will cover Ch 1 and 2, G2 covers Ch 3 and 4 and G3 will cover Ch 5 and 6.

2. <u>Gain Flatness</u> - This response needs to be measured at high gain drive levels where the gain expansion is maximum (5 dB) and at small signal levels (max drive minus 20 dB). Gain flatness specification should be the same. A preliminary spec of $\pm$0.1 dB at constant drive is obtained from the driver amplifier spec.

3. <u>Gain</u> - The Linearizer gain consist of that obtained in the module plus the select-by-test attenuator at the output. The SBT value is chosen at transponder level test and is dependent on the type of amplifier being linearized. The maximum linear, small signal gain is TBD, the maximum saturated gain is SSG plus 5 dB.

4. <u>Gain Stability vs. Time</u> - TBD.

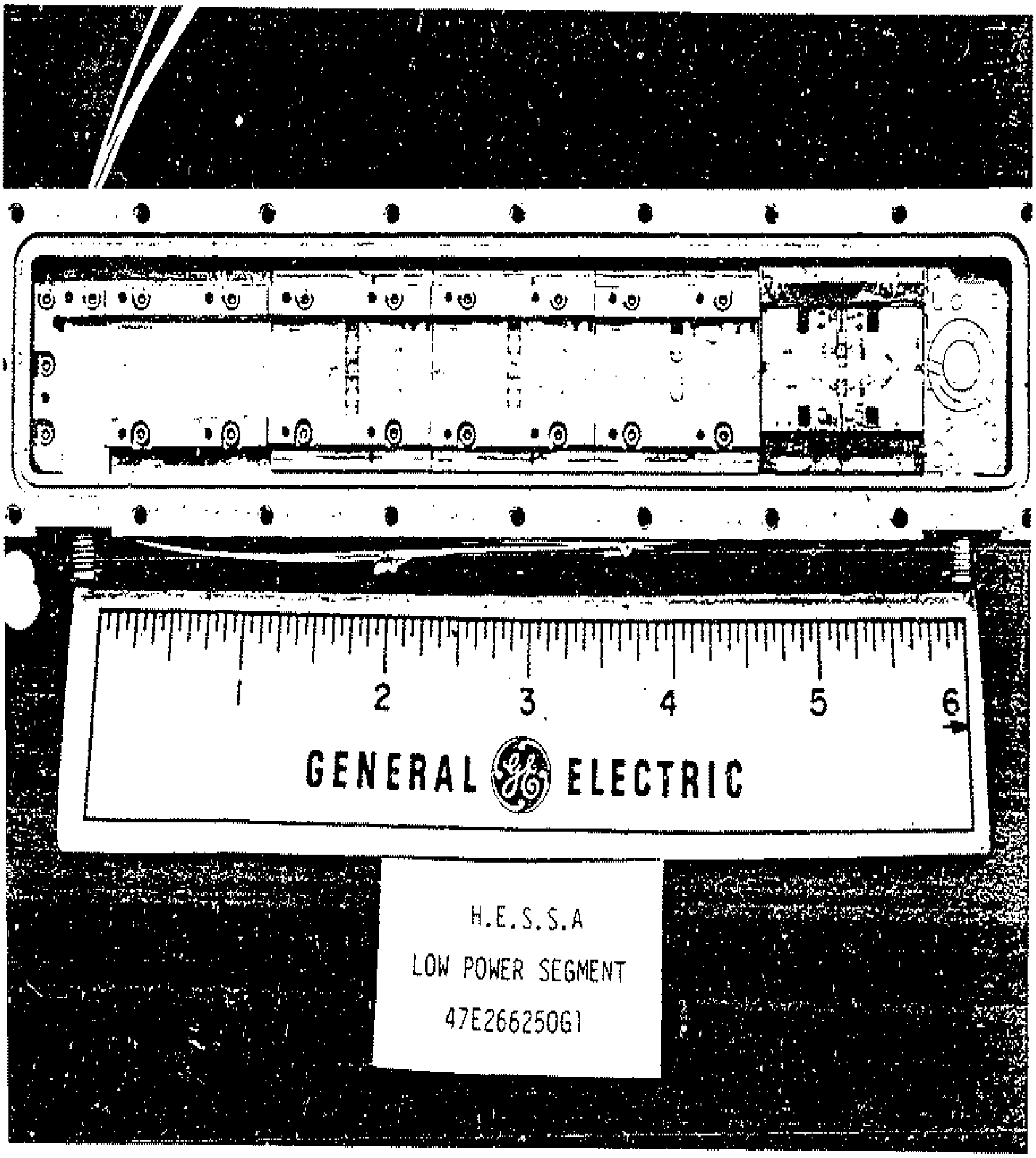


Figure 2.6-4. Linearizer Assembly

5. Gain Stability vs. Temperature - The Linearizer will need to be temperature compensated. While a constant figure over the qualification temperature range is desired, it may be required that 3 ranges be identified (similar to Driver Amplifier spec). A preliminary spec is:

±0.4 dB	-13°C to 50°C
±0.5 dB	-24°C to 61°C
±0.6 dB	-24°C to 71°C

6. Out of Band Response - TBD

7. Noise Figure - 8 dB.

8. Gain Compression - Gain below small signal gain, 0.5 dB maximum.

9. Phase vs. Input Power - TBD - This parameter is one of the control elements of the Linearizer. Limits have not been evaluated.

10. Deviation from Linear Phase - ±1 degree over any channel.

11. Input and Output VSWR - The input is a balanced amplifier and the output contains a chip isolator.

Input	1.5:1
Output	1.3:1

12. Amplifier Stability - Unconditionally stable.

13. Spurious Outputs - TBD.

14. Prime Power - The Linearizer shall operate from the +8V and -12V rails available from the NPPC. The maximum loads on these rails are: 80 mA from the +8V line and, 25 mA from the -12V line.

15. Thermal Dissipation: 0.94 watts maximum.

16. Temperature

Operating (Qualification)	-34°C to +71°C
Operating (Acceptance)	-24°C to 61°C
Non-operating (Storage)	-40°C to 85°C

17. Useful Life - 10 years.

It is necessary to demonstrate that the Linearizer is capable of improving the intermodulation results of a transmit amplifier when operated in cascade. It is therefore necessary to connect the unit with an amplifier (10 W TWTA, 10 W HESSA, 40 W TWTA) as a demonstration. Intermod specification at specific levels (P_{sat}, P_{sat} -3 dB, P_{sat} -6 dB) will be required.

2.6.4 BENEFITS OF SELECTED APPROACH

A Linearizer when cascaded with a transmit amplifier will improve the linearity performance. The linearity improvement of the system will then permit higher traffic, and increased communication capacity.

2.6.5 SYSTEM IMPACT

Incorporation of the Linearizer in front of the 10 or 40 Watt transmit amplifiers on the MYP DSCS III spacecraft has nominal impact and minimum overall program risk. The Linearizer will be designed to require no modifications to present spacecraft structural, power, or thermal designs. A suitable mounting location, probably on the North Panel Shelf needs to be determined. The Linearizer design is small, light weight and consumes and dissipates little power.

Power and RF interconnection to the Linearizer require minor modifications to the spacecraft electrical wiring and new coaxial cables to interface with the driver amplifier on the input side and with the transmit amplifier on the output side.

2.6.6 RISKS OF SELECTED APPROACH

1. Development - The development risks for the Linearizer are minimal since the concept has been proven using a breadboard to achieve 6 dB IM improvements with Solid State Amplifiers both at the 10 and 32 Watt level. The component is on the order of size of the HESSA Low Power Amplifier and contains piece parts and modules which have been shown to be flight worthy. The only new element are the Dual Gate FETs which need to be negotiated, qualified and procured. Risks in this area is small because of the similarity to small signal FETs.

2. Production Risks - The amplifier is about the complexity of the Low Power Segment of the BIO HESSA. The principal electrical change is the replacement of the output power stage with a dual gate predistortion stage. Similar amplifier modules, PIN diode attenuation modules, output isolator modules and a simuliar printed wiring board assembly will be used. The chassis will be modified to accommodate any changes. The Low Power Segment of the HESSA has not experienced production problems. The similar Linearizer component should exhibit a low producibility risk.

2.6.7 RATIONALE

The Linearizer approach uses the predistortion method of improving the linearity performance of transmit power amplifiers. It may also be found to be useful to linearize the FETAL. A measurement will be made to assess the improvements that can be obtained.

2.6.8 BREADBOARD LINEARIZER TEST DATA

A two stage Breadboard Linearizer consisting of a single dual gate FET stage following a single balanced amplifier stage was fabricated, tuned and tested. Only a cursory tuning was performed so that more evaluation test data could be obtained using the Linearizer with transmit power amplifiers. The unit was ultimately mated to three types of amplifiers: the Engineering Model HESSA, B4/B5 design; a 10 Watt TWTA and the Engineering Model 32 Watt HPSSA. Test results of the Linearizer by itself and mated with the three power amplifiers are given below. In the limited time available for this study only limited test data could be obtained. Test data over temperature and true optimization where phase compensation would be performed was not obtained.

2.6.8.1 Two Stage Linearizer Test Data

The basic approach taken here is to obtain an improvement in the AM/AM characteristics by introducing a non-linear increasing gain characteristic which compensates for the normal decreasing gain characteristics of a transmit amplifier. The combination would then provide a well-defined linear gain characteristic until saturation occurs. The gain curve would exhibit a sharp saturation break. Since the phase compensation characteristics of the Linearizer was not evaluated, the phase effect is not yet known. The unique

AM/AM characteristics of the Linearizer is shown in Figure 2.6-5 which shows gain increase with increasing input power. The actual gain is negative for the two stage devices. Additional gain stages would be required in the completed device so that the overall gain requirement is met.

Figure 2.6-6 is the frequency response for the two stage Linearizer. The response is best in channels 3 and 4. However, the response was adequate to show that the channel 1/2 HPSSA and channel 6 HESSA could be compensated. Figure 2.6-7 shows that the phase change vs. drive is not large (9.8 degrees) and well balanced. While not done, the phase change could be increased to provide phase as well as amplitude compensation.

2.6.6.2 Two Stage Linearizer/Engineeing Model HESSA Test Data

The two-stage Linearizer module was tested and aligned with the Engineering Model HESSA, B4/B5 design. This design had a coaxial output connector which has since been replaced for new units with a waveguide output. Baseline data for the HESSA was taken from which improvements could be obtained. The key parameter is the intermodulation performance as it is calculated for B8 and subsequent HESSAs. The intermodulation data and the single tone power transfer curve is shown in Figure 2.6-8 along with the baseline performance at saturation, Sat -3 dB and Sat -6 dB. Figure 2.6-9 shows the rounded gain vs. drive which have been associated with higher nonlinear levels. Figure 2.5-10 shows the phase vs. drive curve for the HESSA alone. These phase change characteristics appear to be opposite of that obtained for the Linearizer alone. The next several figures demonstrate the effect obtained when the two stage Linearizer is cascaded with the EM HESSA. Figure 2.6-11 shows intermod performance of the Linearizer coupled to the EM HESSA. Improvements were made at P_{sat} -3 and P_{sat} -6 of 8.40 and 5.79 dB, respectively while decreasing the measurement at P_{sat} by 0.59 dB. The decreased IMD is 1.46 dB within the current specification. The results obtained here would obtain limited overall channel improvement because the limiting amplifier (FETAL) IMD performance would dominate and need to be improved. Figure 2.6-12 shows the sharp break

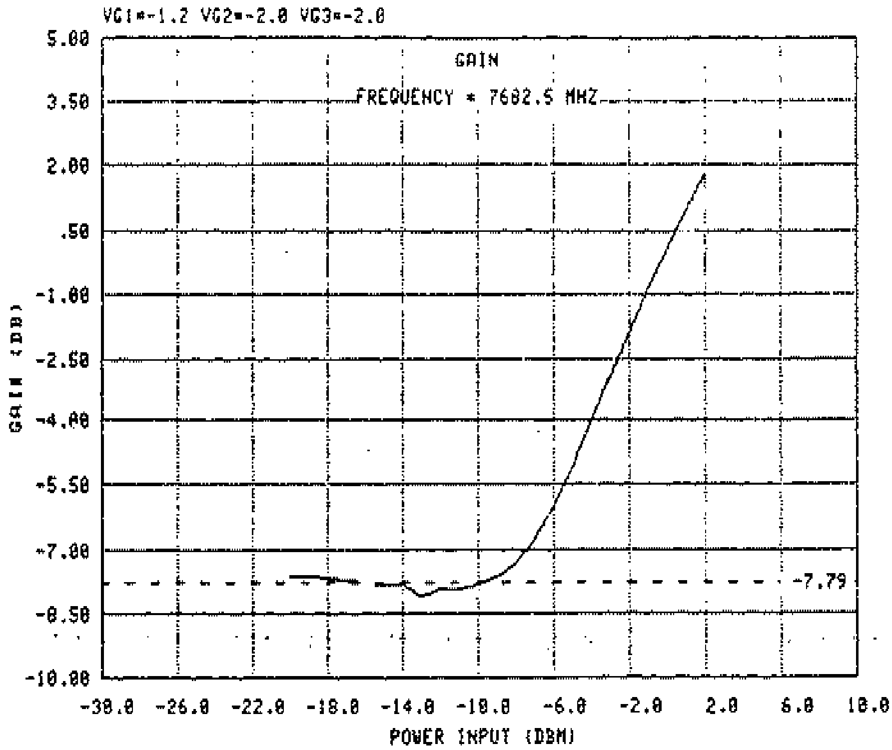


Figure 2.6-5. Two Stage Linearizer AM/AM Gain Characteristics

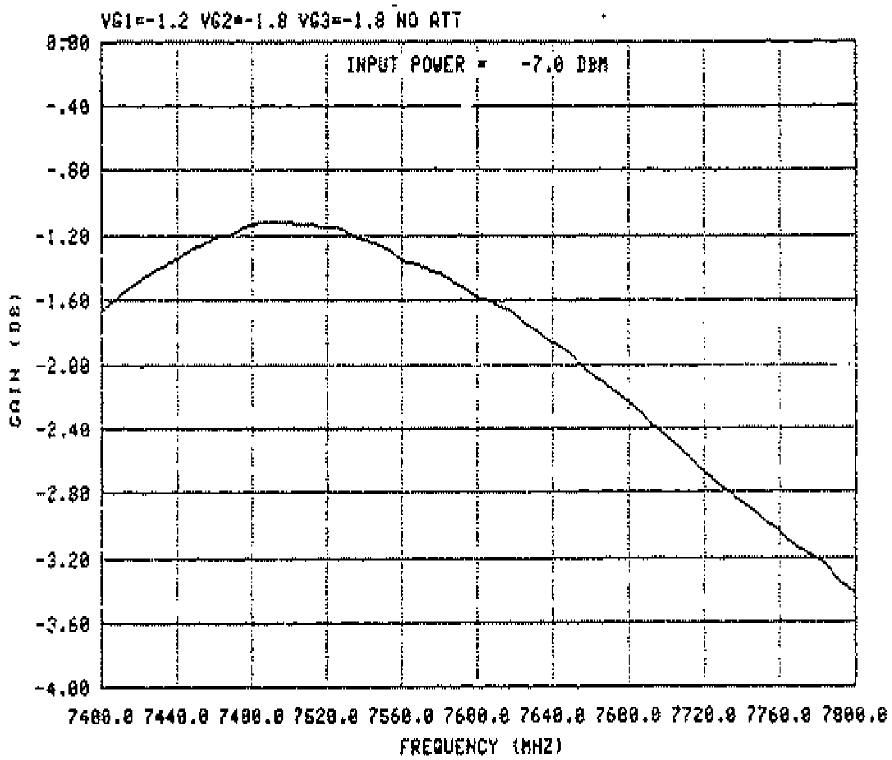


Figure 2.6-6. Two Stage Linearizer Frequency Response

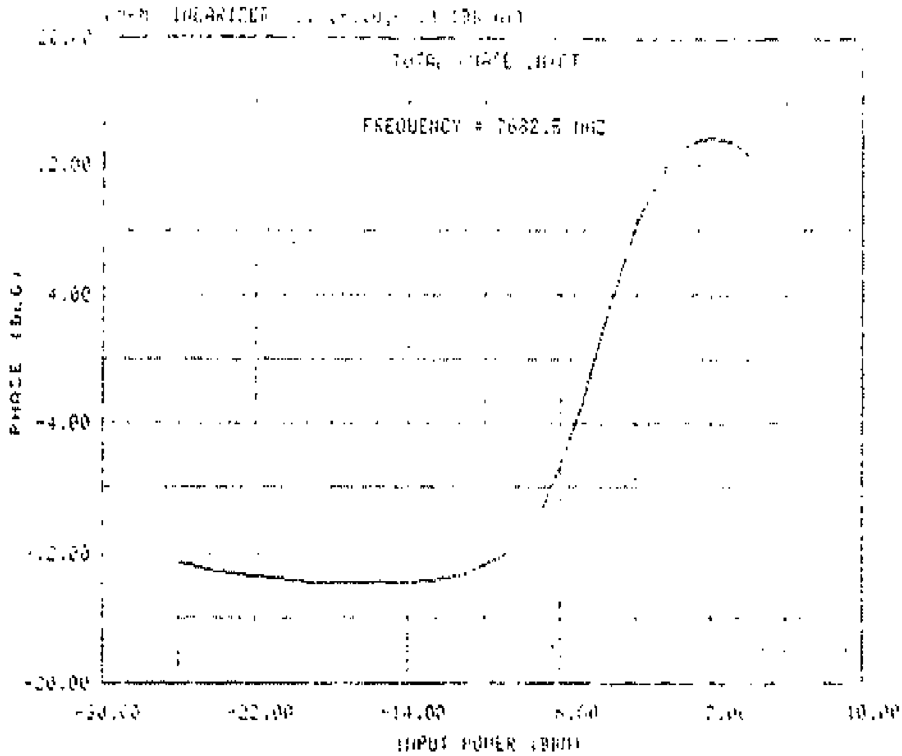
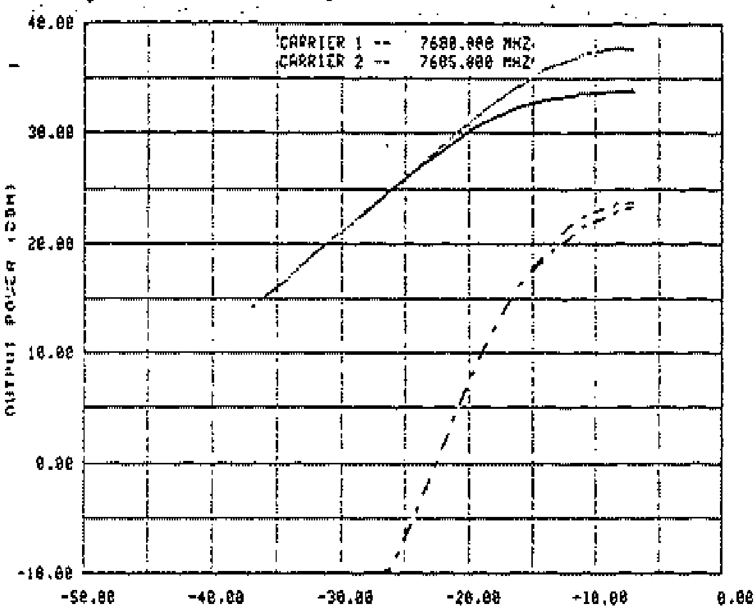


Figure 2.6-7. Two Stage Linearizer Phase Characteristics



	3RD (dBc)
SAT. POINT	-11.55
-3dB	-21.42
-6dB	-28.69

Figure 2.6-8. Baseline HESSA Intermod Performance

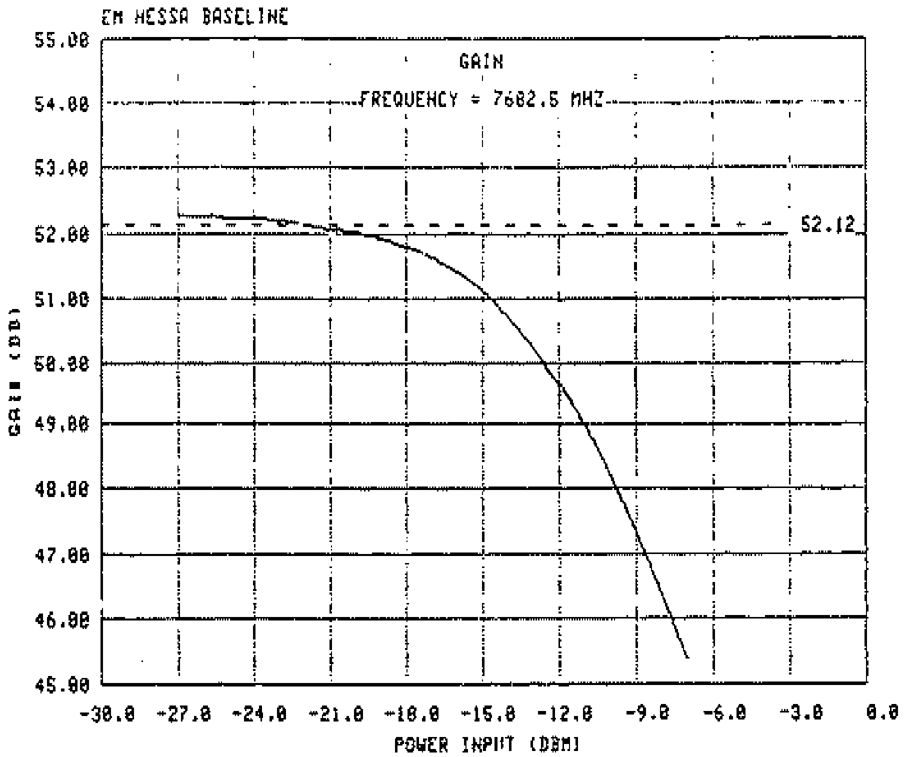


Figure 2.6-9. Baseline HESSA Gain - Drive Characteristics

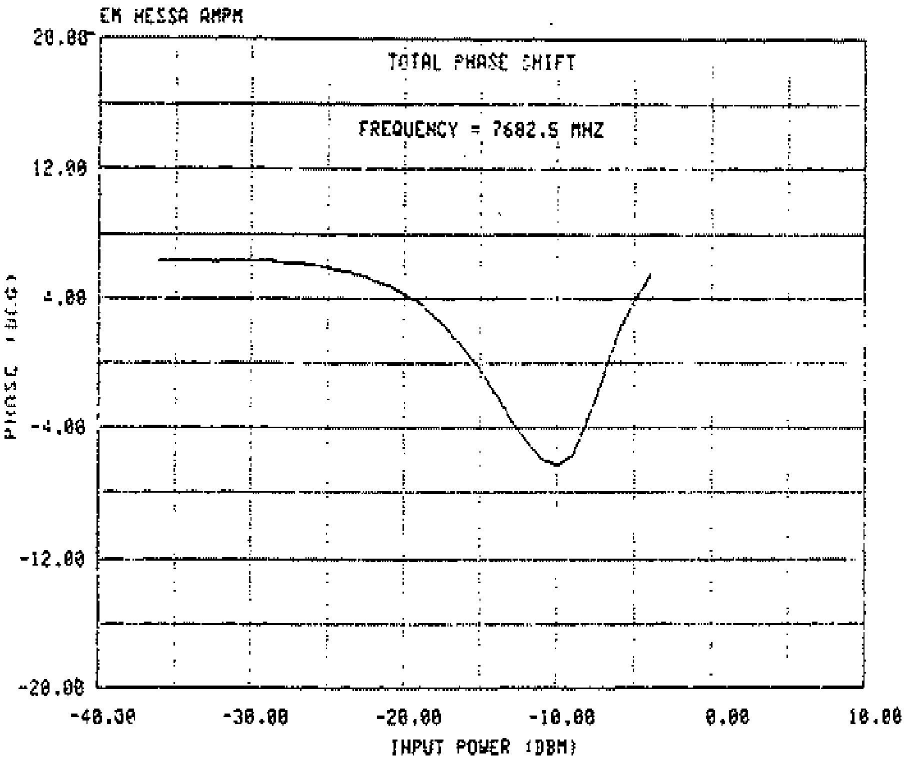
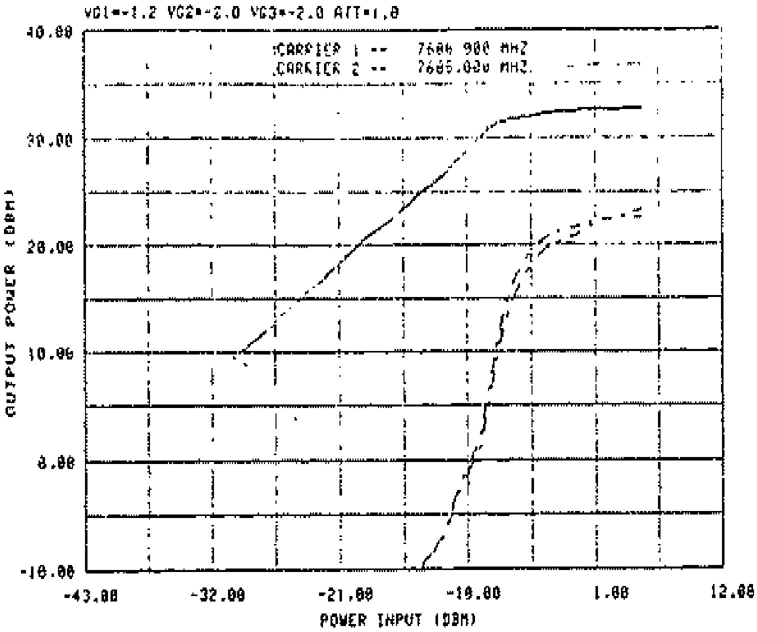


Figure 2.6-10. Baseline HESSA Phase Characteristics



	3RD (dBc)	IMPROVEMENT (dB)
SAT. POINT	-10.96	-0.59
-3dB	-29.82	8.40
-6dB	-34.48	5.79

Figure 2.6-11. Linearizer/HESSA Intermod Performance

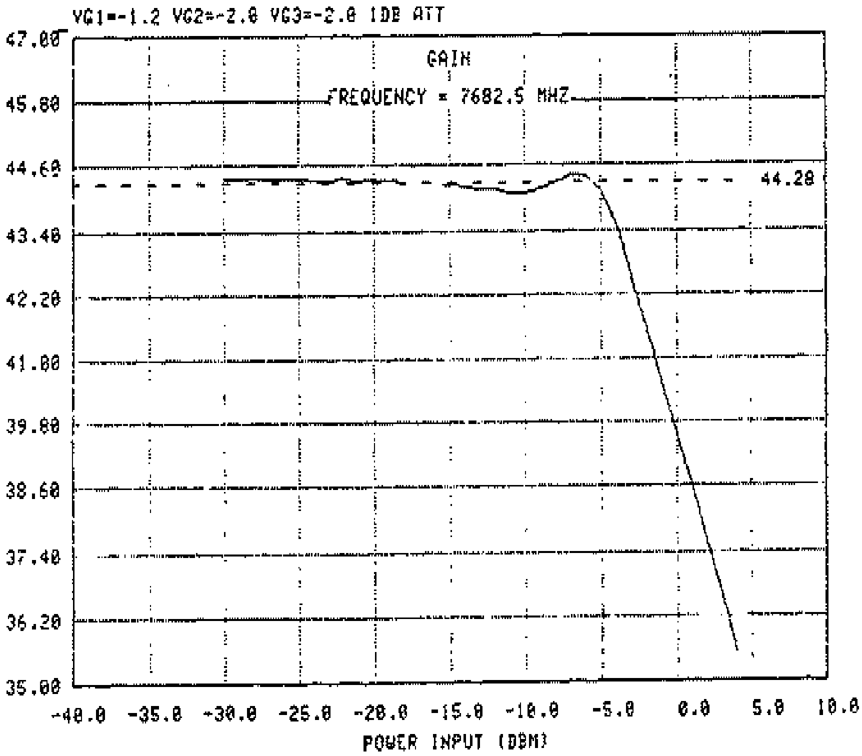


Figure 2.6-12. Linearizer/HESSA Gain Characteristics

characteristics of the gain plot. Figure 2.6-13 shows the phase characteristics indicating excessive AM/PM slope and that more study is required to understand and curtail this effect. This may be caused by a slight mis-alignment of the Linearizer with the HESSA.

2.6.8.3 <u>Two Stage Linearizer/Engineering Model High Power Solid State Amplifier (HPSSA)</u>

Similar tests were run with the Engineering Model HPSSA (32W) which was designed to replace 40 Watt TWTAs used in channel 1 and 2. Figure 2.6-14 shows the intermod performance. Figure 2.6-15 shows the gain-drive curve which will become sharper when coupled to the Linearizer. Figure 2.6-16 shows the phase characteristics which are markedly different than that obtained for the HESSAs. The next three figures are comparable except the Linearizer is driven in front of the HPSSA. Figure 2.6-17 shows the intermodulation results. Again improvements are obtained for P_{sat} -3 and P_{sat} -6 of 9.39 and 13.71 dB, respectively. IMDs at P_{sat} decreased by 0.83 but was well within specification of 9.5 dBc. Figure 2.6-18 is the combined gain performance. This is a case where the gain curve break obtained is sharper than in other measurements. Figure 2.6-19 is the associated phase plot which is very well bahaved compared to the corresponding HESSA plot.

2.6.8.4 <u>Two Stage Linearizer/10 Watt Traveling Wave Tube Amplifier (TWTA)</u>

This section describes the test results obtained with a 10 W TWTA mated to the Linearizer. Tests with a TWTA were not as successful with amplitude linearization presumably because a large portion of a TWTA's intermodulation is caused by phase rather than amplitude nonlinearities. Phase linearization was not attempted although the Linearizer has that capability. Still, some improvements were noted with amplitude linearization.

Figure 2.6-20 is the intermodulation data for the 10 Watt TWTA. Note the rounded saturation characteristics. The calculations for 3rd order IMD assumes 5 dB compression and the HESSA method of calculation. Figure 2.6-21 shows the very rounded gain characteristics of the TWTAs. Figure 2.6-22 shows

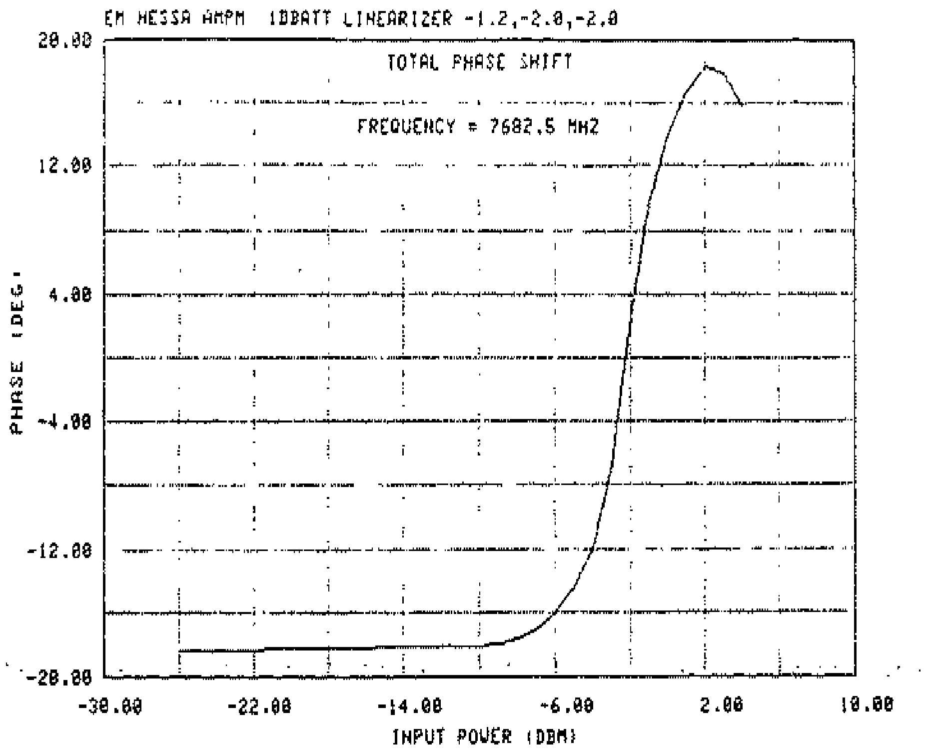
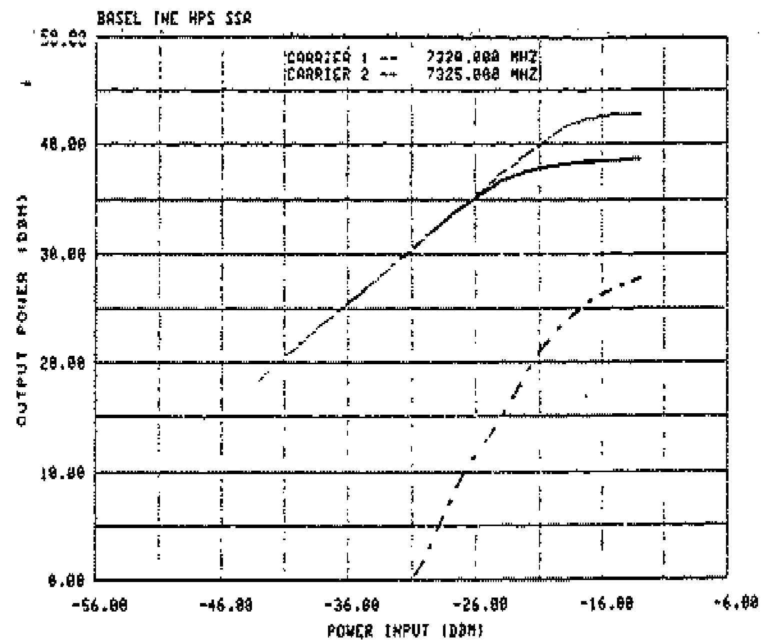


Figure 2.6-13. Linearizer/HESSA Phase Performance



	3RD (dBc)
SAT. POINT	-12.59
-3dB	-23.06
-6dB	-27.38

Figure 2.6-14. Baseline HPSSA Intermod Performance

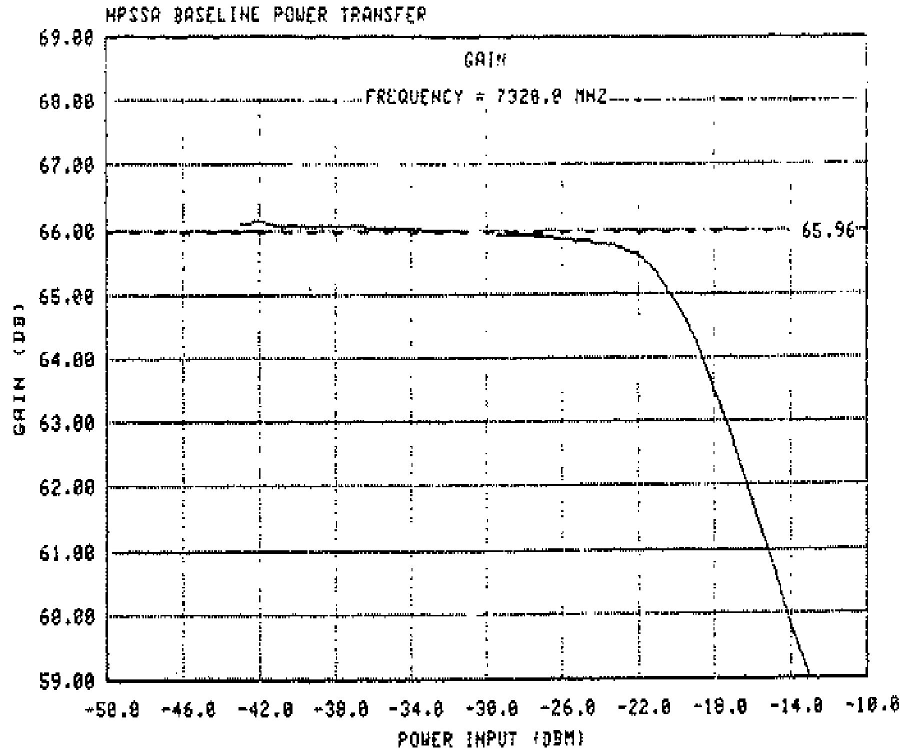


Figure 2.6-15. Baseline HPSSA Gain Characteristics

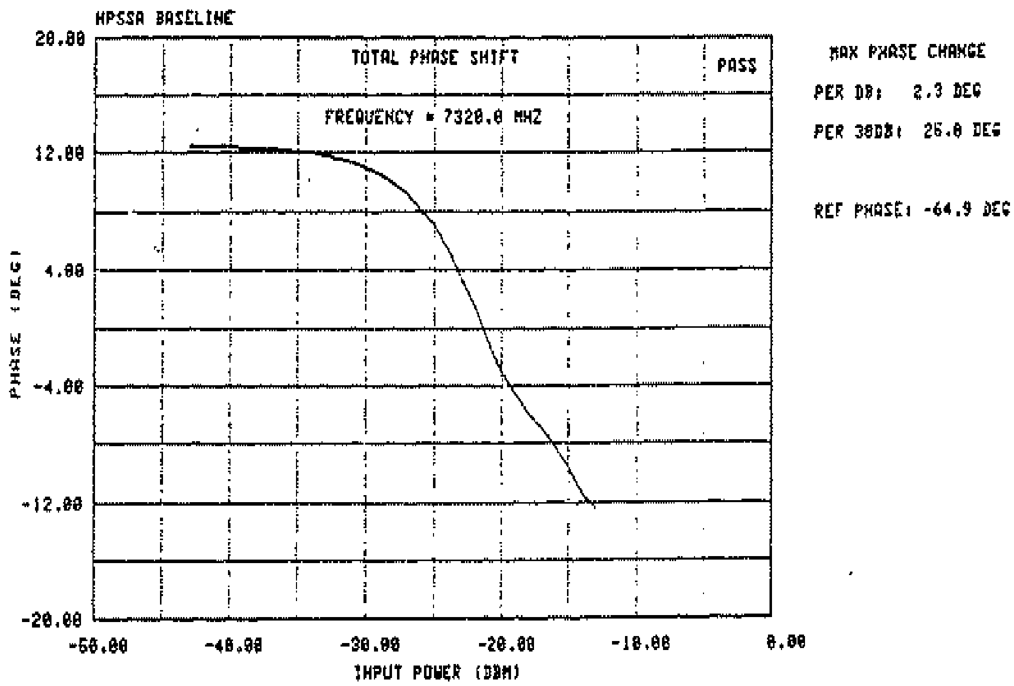
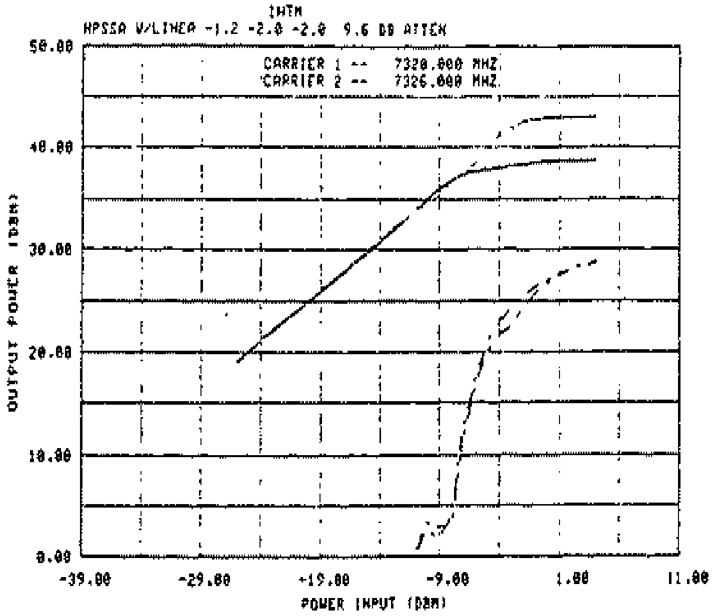


Figure 2.6-16. Baseline HPSSA Phase Characteristics



	3RD (dBc)	IMPROVEMENT (dB)
SAT. POINT	-11.76	-0.83
-3dB	-32.45	9.39
-6dB	-41.09	13.71

Figure 2.6-17. Linearizer/HPSSA Intermod Performance

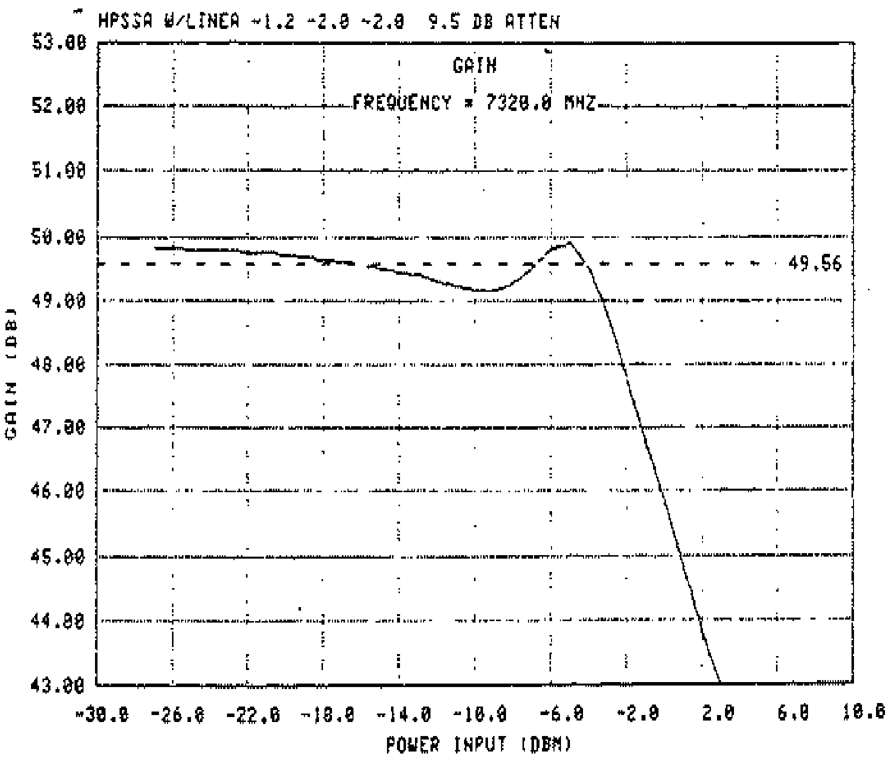


Figure 2.6-18. Linearizer/HPSSA Gain Performance

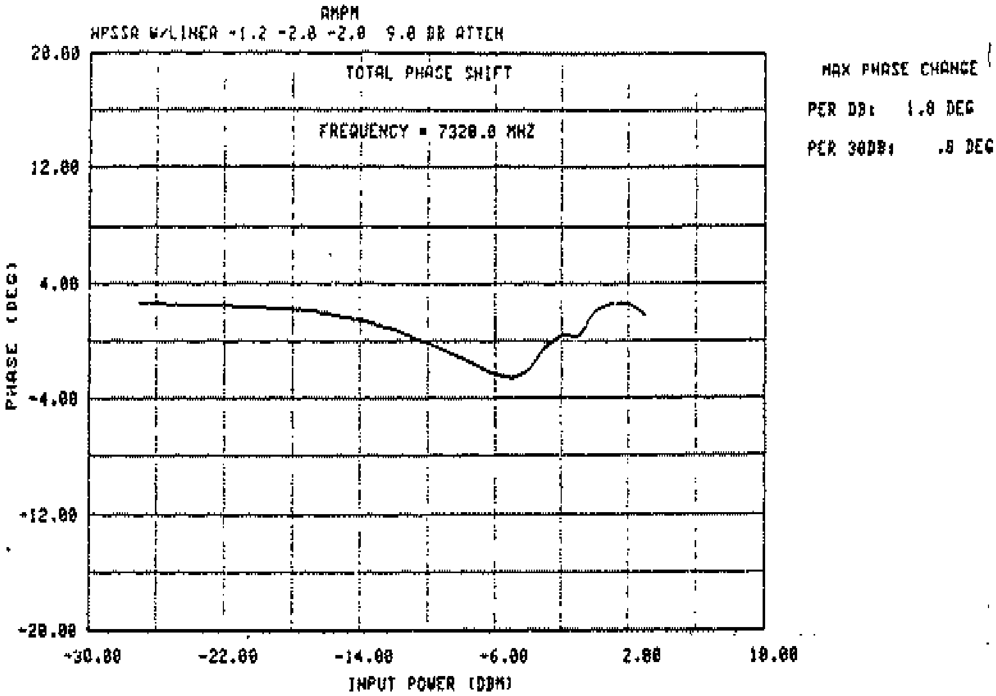
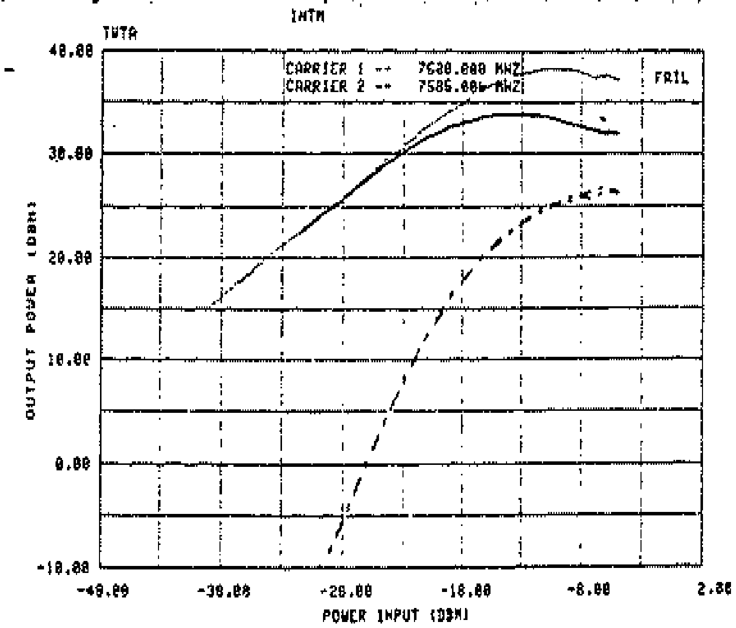


Figure 2.6-19. Linearizer/HPSSA Phase Characteristics



	3RD (dBc)
SAT. POINT	-11.42
-3dB	-20.68
-6dB	-26.68

Figure 2.6-20. Baseline TWTA Intermod Data

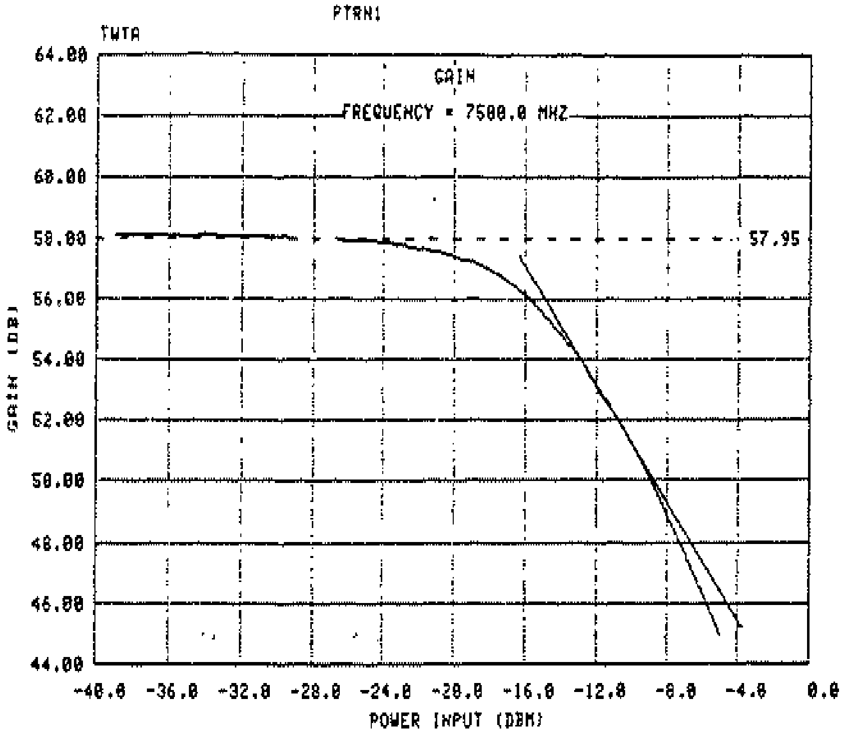


Figure 2.6-21. Baseline TWTA Gain Characteristic

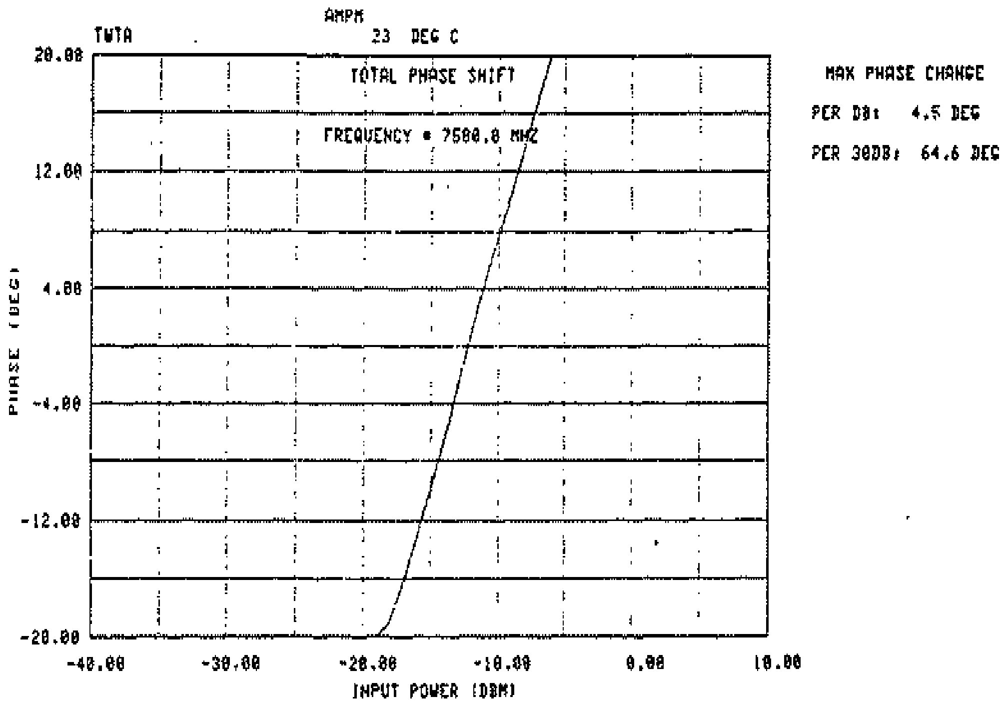


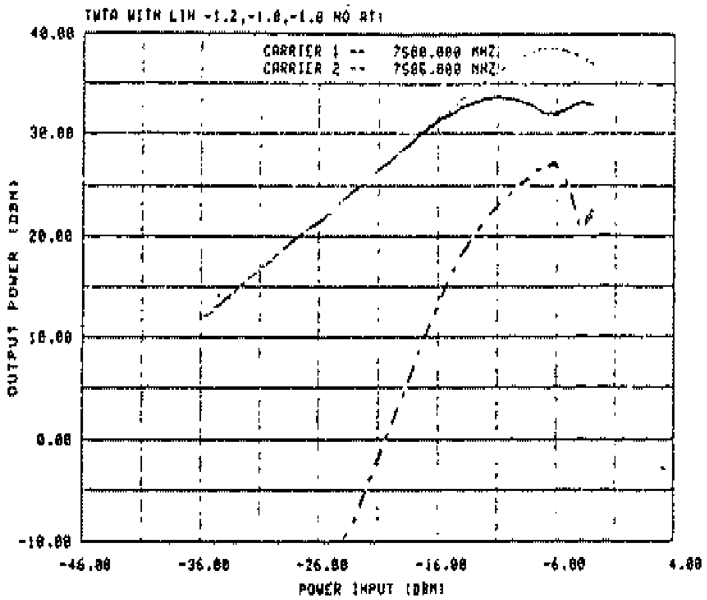
Figure 2.6-22. Baseline TWTA Phase Characteristics

that the TWTA phase characteristics is much larger than that obtained for the HESSA or the HPSSA. In this case phase adjustment could have improved the combined Linearizer/TWTA characteristic shown in Figure 2.6-23. Slight improvements were obtained at the expense of the saturated level intermod level. The AM/AM performance of Figure 2.6-24 shows a sharper break but the the AM/PM performance of Figure 2.6-22 was not changed significantly as shown in Figure 2.6-25. Linearizer phase adjust could dramatically improve the measured results.

2.6.8.5 Intermodulation Improvement Summary

The Linearizer was able to improve the third order intermodulation performance when connected to GaAs FET transmit amplifiers but did not show such improvements when connected to a TWTA. This may be due to the phase compensation capability of the Linearizer not being used. Unlike the GaAs FET amplifier which show small phase deviations the TWTA exhibit larger phase changes than the Linearizer as presently studied can handle. The table below summarizes the IMD performance for the 3 types of amplifiers tested.

	IMD at P_{sat}	IMD at P_{sat} -3dB	IMD at P_{sat} -6dB
HESSA Baseline Linearizer/HESSA Improvement	-11.55 -10.96 - 0.59	-21.42 -29.82 + 8.40	-28.69 -34.48 + 5.79
HPSSA Baseline Linearizer/HPSSA Improvement	-12.59 -11.76 - 0.83	-23.06 -32.45 + 9.39	-27.38 -41.09 +13.71
TWTA Baseline Linearizer/TWTA Improvement	-11.42 - 5.99 - 5.43	-20.68 -22.17 + 1.49	-26.68 -28.07 + 1.39



	3RD (dBc)	IMPROVEMENT (dB)
SAT. POINT	-5.99	-5.43
-3dB	-22.17	1.49
-6dB	-28.07	1.39

Figure 2.6-23. Linearizer/TWTA Intermod Characterization

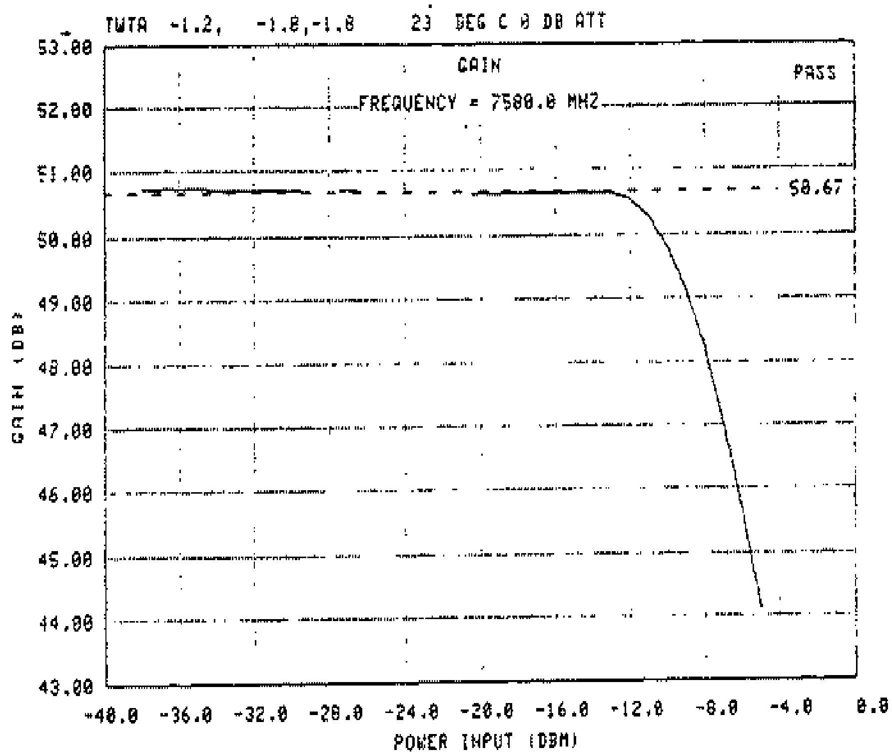


Figure 2.6-24. Linearizer/TWTA Gain Performance

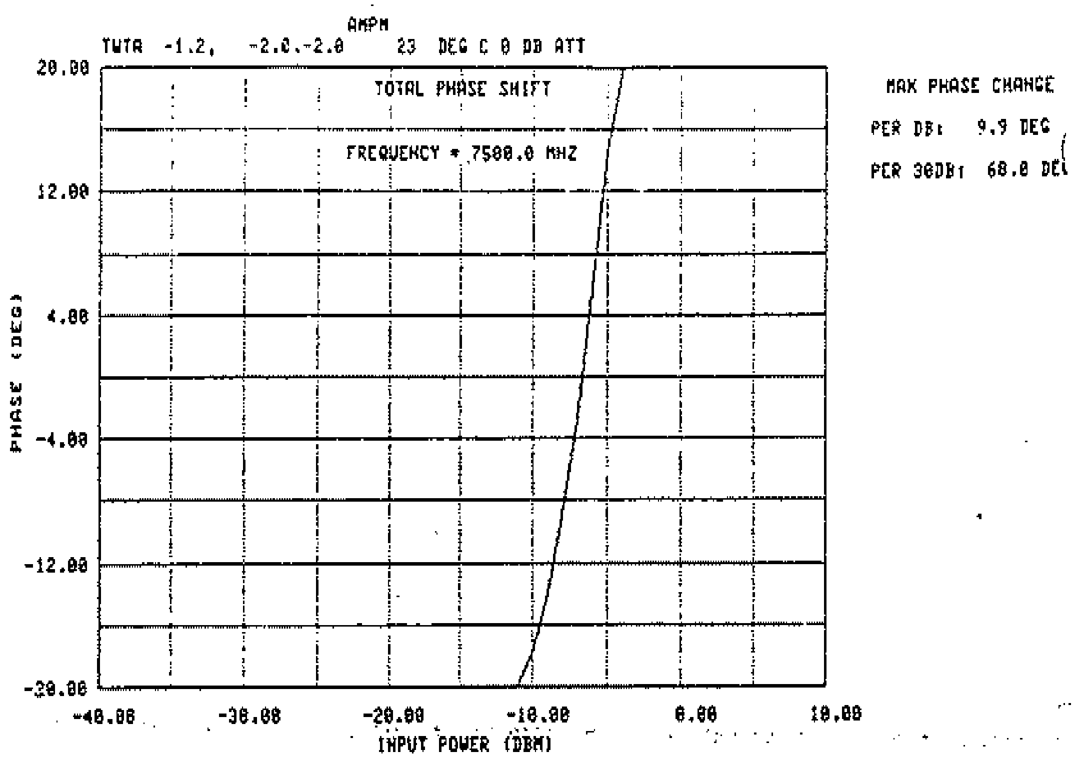


Figure 2.6-25. Linearizer/TWTA Phase Performance

2.7 IMPROVED ACCURACY TRANSMIT LEVEL SENSOR

The most cost effective approach to an improved TLS accuracy is a North Panel calibration method using white noise coupled with a software change to compensate temperature variation. That solution should be sufficient to meet a TLS accuracy specification (±1 dB) which is applicable from 2 dB below saturation to 10 dB below. Ambiguities in power level due to harmonics have been seen from saturation to 2 dB below even when using the noise calibration (Figure 2.7-1.). However, in order to provide unambiguous power monitoring into the saturation region the hardware change described below in Section 2.7.1 is required. More detail on the improved calibration method is covered in Section 2.7.2.

2.7.1 HARDWARE MODIFICATION APPROACH

2.7.1.1 Description

The changes in the TLS component are intended to reduce the detector sensitivity to the second harmonic by filtering within the directional coupler transition. The modifications are dimensional changes in the upper guide

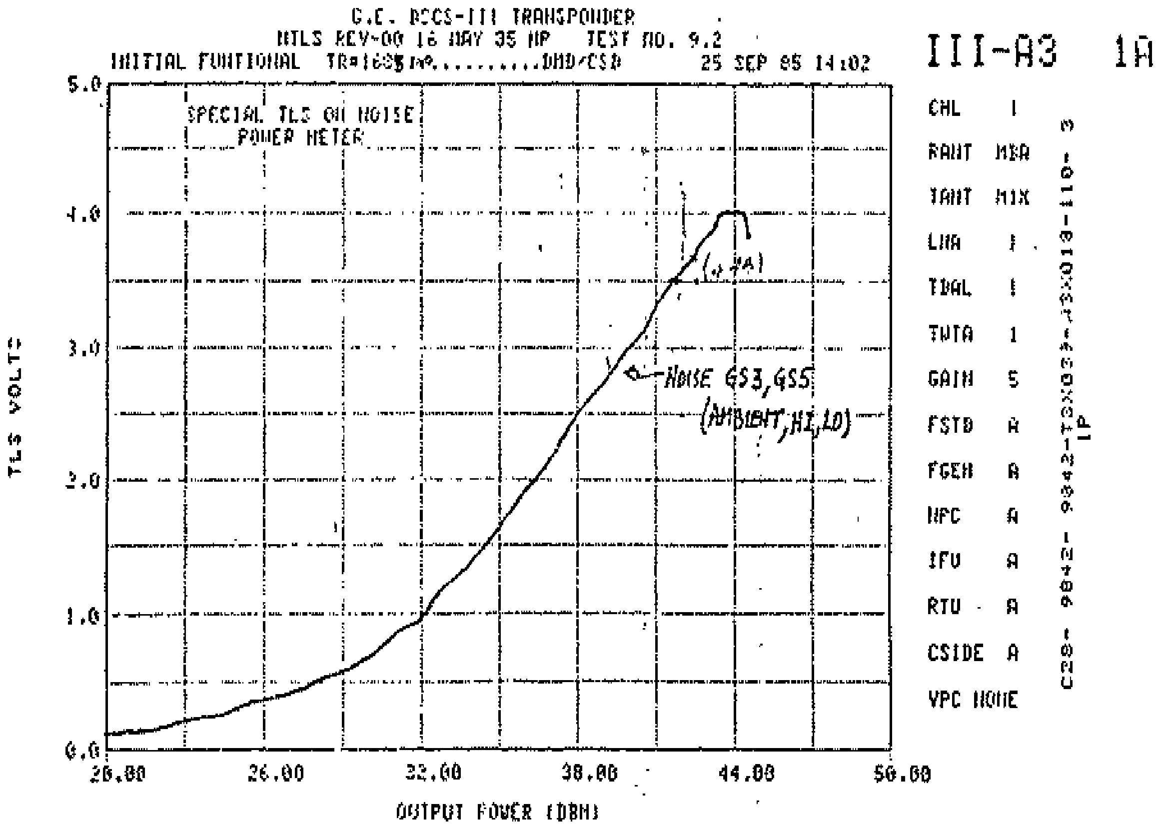


Figure 2.7-1. Representative TLS Calibration Curve using Noise Source

height, coupling slots, and probe transition region of the dip brazed directional coupler and the addition of filtering in the diode housing. The redesign has negligible weight increase and no power impact. The new component will fit in the same envelope as the current design and will require no waveguide or telemetry interface modifications.

The required changes in the top guide height and probe configuration were incorporated on a brass board coupler (Figure 2.7-2). As in the current device, the ligthweight dip brazed housings will be used in the final design.

2.7.1.2 Performance

The modified coupler tuned to channel 4 and the current design were measured at both the fundamental and second harmonic frequency. A minimum improvement in second harmonic rejection of 14 dB was realized. It may be seen from the results in Table 2.7-1 that there exists a preferential coupling of 9 dB for the second harmonic in the current design.

2.7.1.3 Benefits and Impacts of Approach

The new TLS will provide more accurate output power estimates for the channel operation control system when the TWTA or SSA is near saturation. Improving this measurement provides more efficient use of FDMA resources during high traffic periods. The improvement also allows more accurate monitoring of the SSA or TWTA performance on the spacecraft.

The change is designed to have no impact on the North Panel. No waveguide runs need modification. The telemetry interface and specification is preserved. No SCCE software changes will be required. The modification is compatible with the noise calibration technique.

2.7.1.4 Risks

Although the preliminary results from the EM tests give high confidence in the new design's ability to reject second harmonic, a test of the component in the North Panel has not been conducted. The primary risk is that another

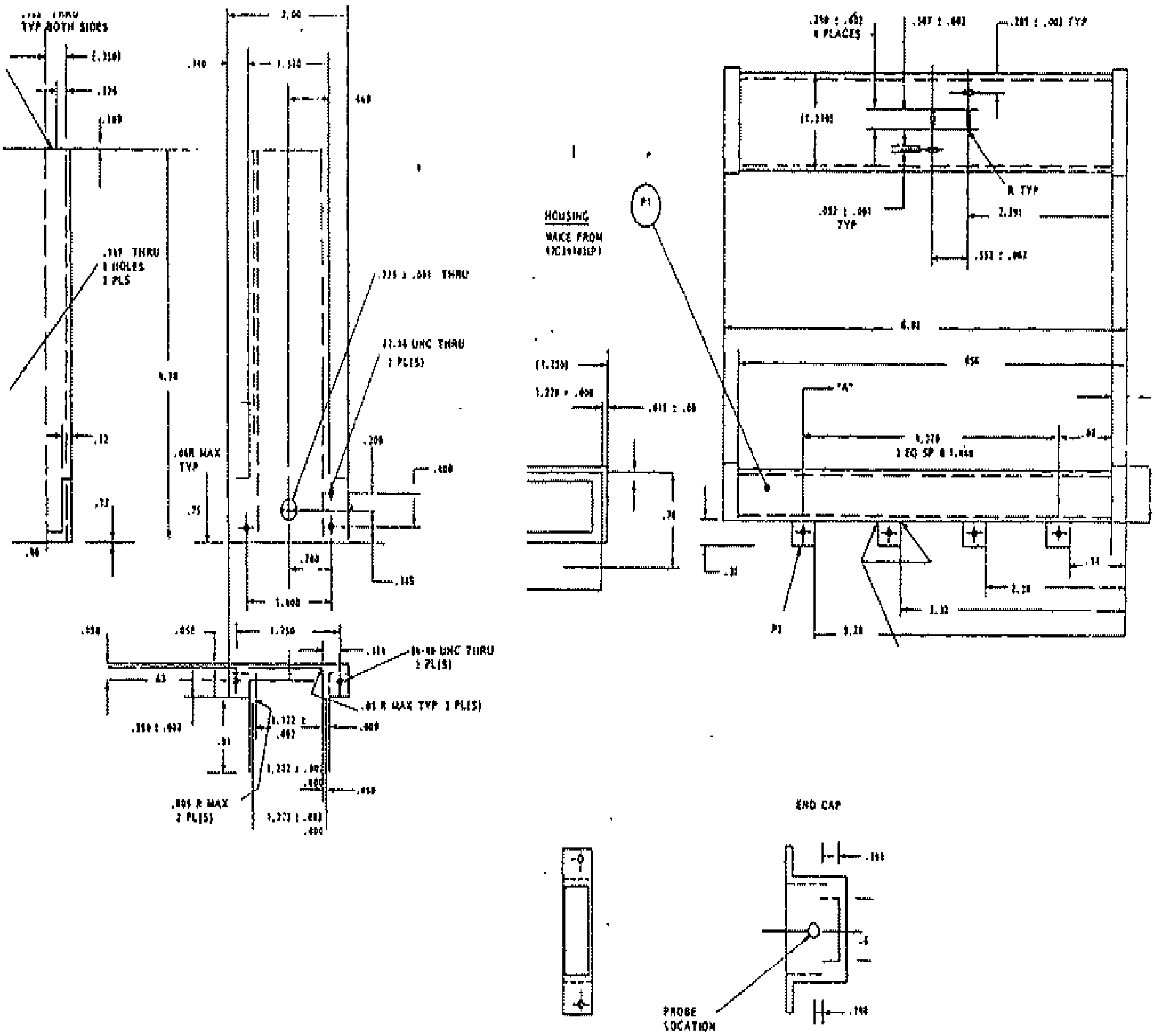


Figure 2.7-2. TLS Brass Board

Table 2.7-1. Second Harmonic to Fundamental Coupling Ratio

Freq (MHz)	Current TLS Design	Modified TLS	Improvement
7507	+9.26 dB	-10.42 dB	19.68 dB
7550	+9.40	-17.14	26.54
7590	+5.81	-8.54	14.35

non-linearity in the TWTA or SSA such as a third or higher order harmonic may also be affecting the TLS performance. This is a difficult test to perform since each TLS/TWTA combination performs differently near saturation.

2.7.1.5 Implementation

This TLS accuracy improvement option must be coupled with the noise calibration technique. This pair of enhancements stand alone and need not be coupled with any other SHF enhancements or hardware changes.

A TLS hardware retrofit on a complete spacecraft would require the removal of the North Panel from the spacecraft and the removal of several covers. The replacement of the TLS requires the unbolting of the component, the unsoldering of the leads, and the replacement of the RF gaskets at the flanges. The subsequent re-acceptance of the North Panel has typically required thermal and acoustic tests at that level. Re-integration testing of the North Panel at the spacecraft level will be required of course, also.

2.7.1.6 Schedule and Cost

Detailed schedules and costs were generated for this hardware change during the IBM proposal. They have been updated for this report. For a 1 Oct 86 start date CDR is 4Q87 (see Figure 2.7-3).

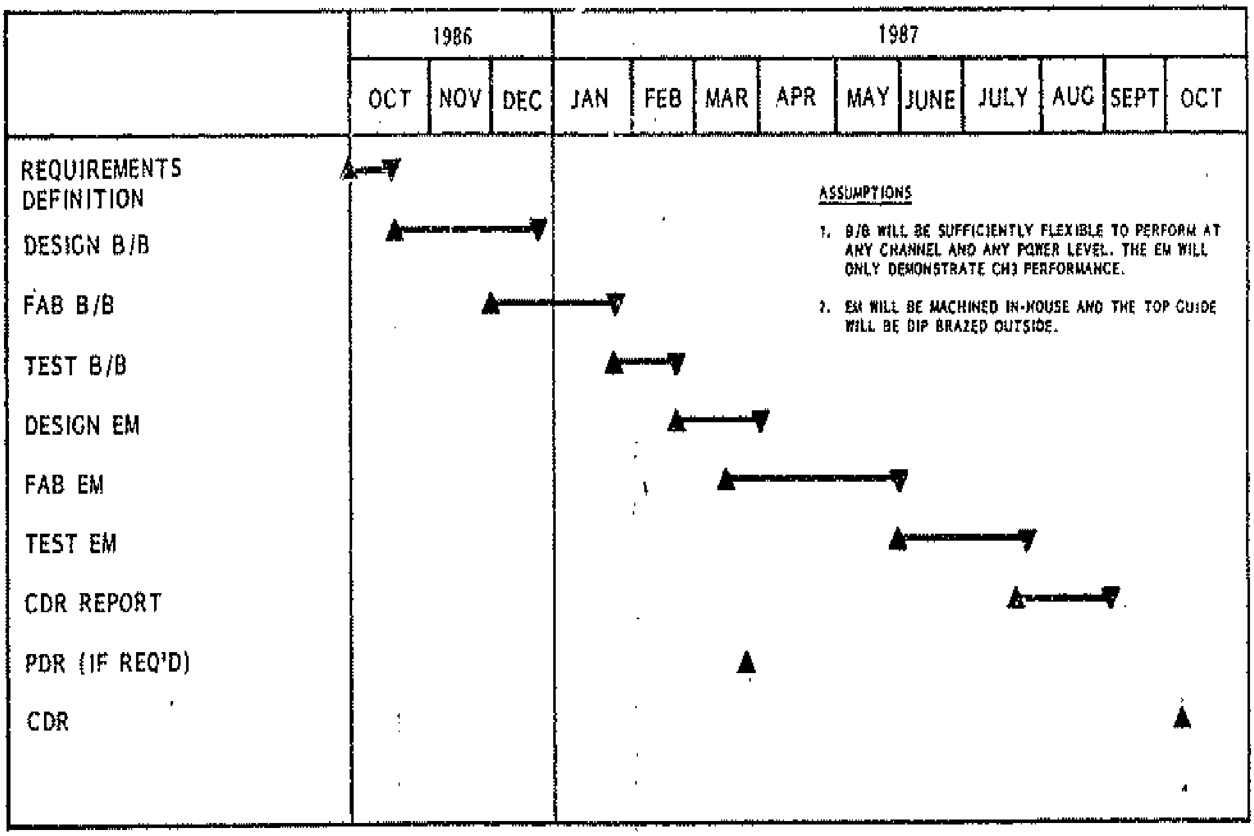


Figure 2.7-3. TLS Redesign Development Schedule

A manufacturing and test lead time of 10 to 12 months would be required after CDR for the first set of 6 TLS. (No change in Beacon TLS' is anticipated.) Thus the first set of units could be available by the B14 North Panel Assembly date, using the assumed 1 Oct 86 start date. Other spacecraft could be retrofitted. For B13, this could be done before assembly of the North Panel to the spacecraft.

2.7.2 TLS ACCURACY IMPROVEMENT - IMPROVED CALIBRATION TECHNIQUES

The selected approach to improving the TLS accuracy for power levels from saturation -2 dB to SAT -10 dB to meet a ± 1 dB specification in temperature (OP high, OP low) is an improved calibration procedure and software temperature interpolation.

2.7.2.1 Description of Approach

A calibration procedure using a noise source has been investigated at the North Panel level as a means for improving the TLS accuracy. Preliminary data has been obtained on B6 and A3. Representative data for comparison of the noise source and single tone data appears in Figures 2.7-4 and 2.7-5.

By using a noise source the relative phase between the fundamental and second harmonic at the TLS detector will vary from frequency to frequency. This decorrelation of phases effectively results in a measurement of the sum of the powers in the fundamental and second harmonic. The single carrier input by contrast yields the power contained in the voltage combination of the fundamental and the second harmonic (see Appendix 1). The power reference in the calibration procedure is measured at the transponder output. In the proposed calibration scheme this measurement is made with a power meter. The output mux has been shown to have 30 dB of insertion loss at the second harmonic thus the power meter measurement is a true indication of the amount of power in the fundamental. This noise calibration method more closely approximates the multiple carrier signal which would be seen on orbit.

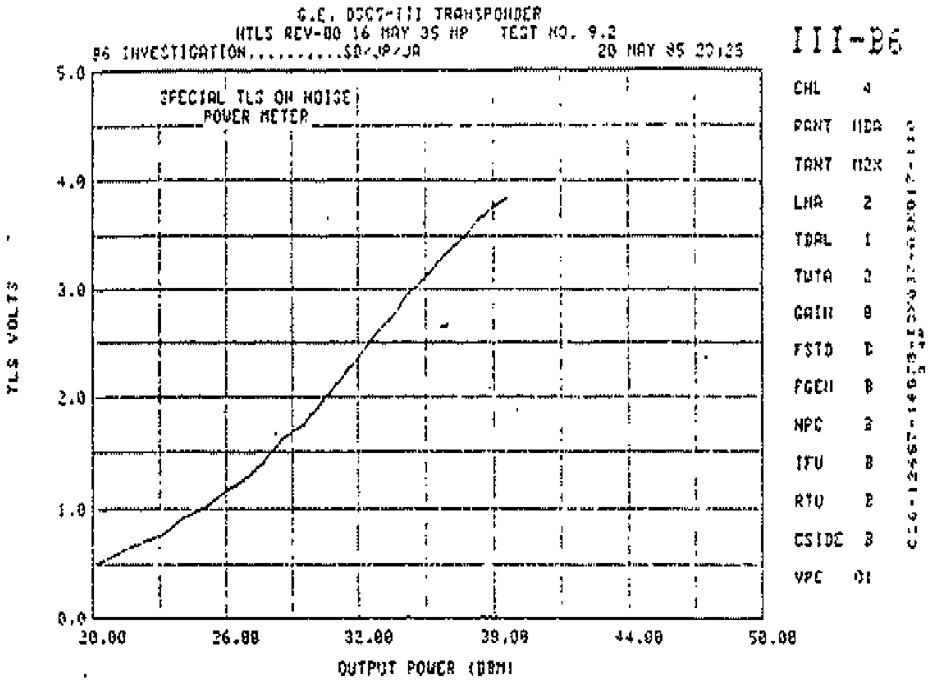


Figure 2.7-4. Channel 4R - TLS Response Using Power Meter and Noise Input

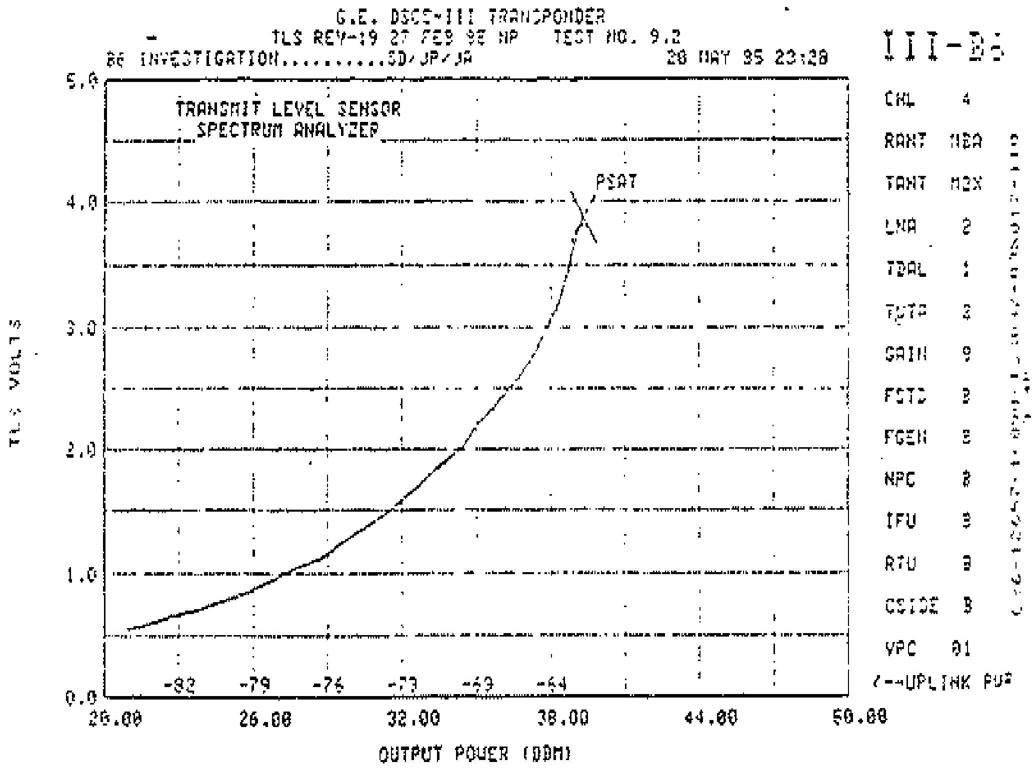


Figure 2.7-5. Channel 4R - TLS Response Using Spectrum Analyzer and Single Tone Input

The calibration will be made in a high gain state (e.g. GS 5). Transponder noise in a lower gain state limits the minimum power which can be measured at the transponder output with the power meter. For no input to the transponder there will be finite amount of output power measured based on the gain state. The single tone calibration using a spectrum analyzer for the output power measurement - which is the current technique - also displays this phenomenon. In a low gain state and at low power input the TLS voltage is asymptotic, indicating the detection of the transponder noise floor. This plateau voltage is seen to decrease as the gain state is raised (see Figure 2.7-6). The noise calibration technique produces the same curve for all gain states but the low input power calibration is only obtainable in a high gain state. Therefore the calibration need only be performed on one gain state.

The current specification requires TLS accuracy to be met over 30 day high and low temperatures (0 - 15°C). On orbit data indicates a temperature range which is wider, swinging 15°C and increasing at a rate of 1.5°C per year (see Figure 2.7-7). In the revised calibration specification it is proposed that calibration data be generated at ambient and in the OP-HI to OP-LO range at sufficiently many temperatures to satisfy an interpolation function which can meet the accuracy requirement from SAT -2 dB to SAT -10 dB in temperature.

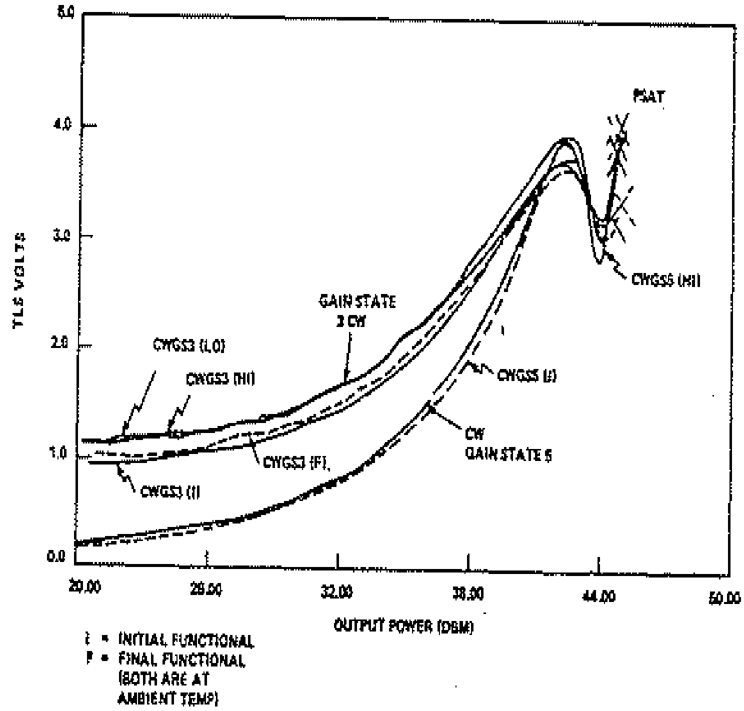
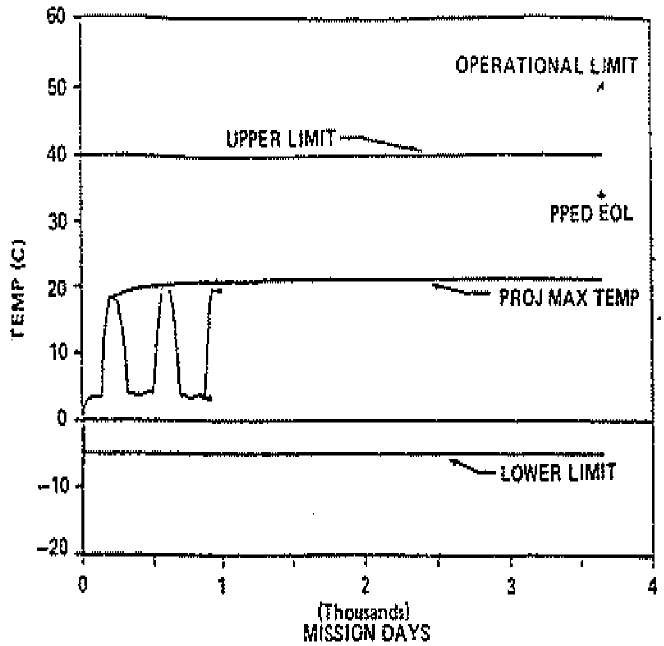
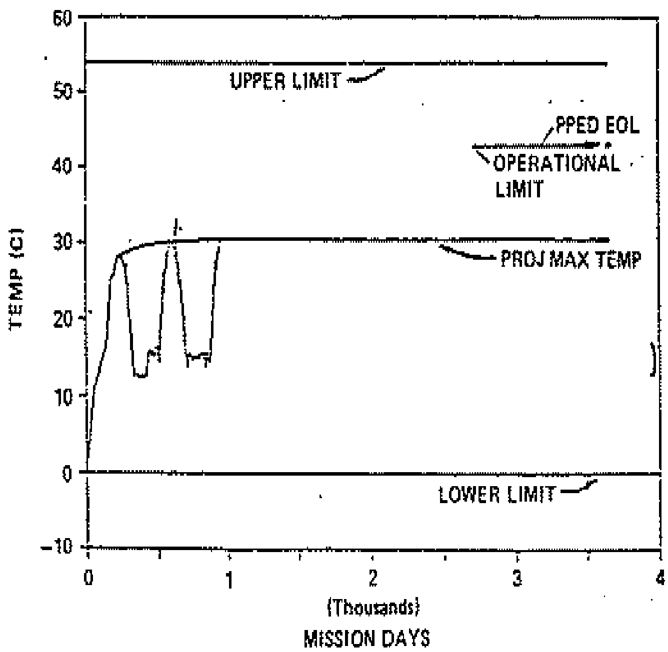


Figure 2.7-6. TLS Response vs. Gain State



TEMPERATURE TRENDS NORTH BAY 2



TEMPERATURE TRENDS NORTH BAY 3

- BASE PLATE TEMP VARIES ~15° YEARLY.
- BASE PLATE TEMP INCREASES ~1.5° PER YEAR.
- BASE PLATE TEMP VARIES ~4° DAILY.
- BASE PLATE TEMP VARIES ~5° WITH DRIVE (MAYBE ONCE A MONTH).

Figure 2.7-7. Thermal Performance in Flight

2.7.2.2 Risks

The noise calibration is a low risk option since ambient and 30 day high and low data has already verified the technique on B6 and A3. The OP-HI and OP-LO temperature data should not be significantly different since this range is not much larger.

2.7.2.3 Implementation

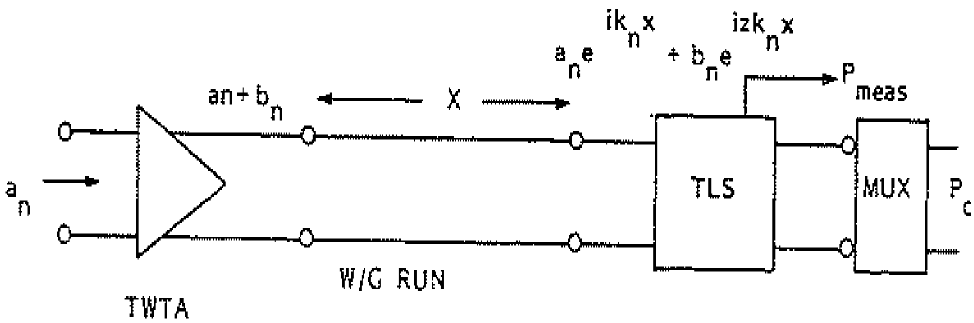
Implementation could be effective once the temperature tests, documentation, and interpolation software is complete. Effectivity could be as soon as A3 and subsequent if immediate authorization were given to proceed. This is a stand alone option and does not require any hardware changes.

2.7.2.4 Schedule and Task List (See Figure 2.7-8)

Attached.

2.7.3 TLS APPROXIMATE ERROR ANALYSIS

Let a_n be the complex amplitude of the n^{th} fundamental in the band. Let b_n be the complex amplitude of the n^{th} 2^{nd} harmonic.



P_0 measured with power meter

$$P_0^{\,m} = \sum_n a_n^2$$

P_0 measured with spectrum analyzer

$$P_0^{\,s} = a_N^2$$

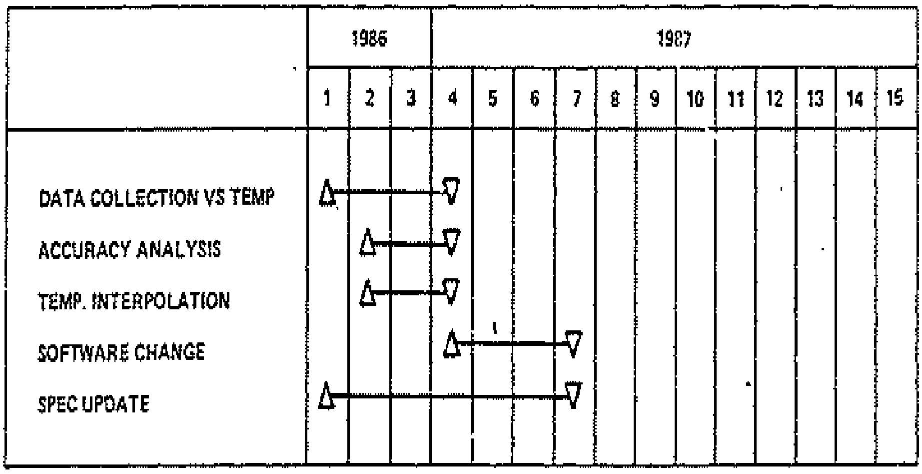


Figure 2.7-8. TLS - Noise Calibration

P_{meas} single carrier input

$$P^{(i)}_{meas} = \left| a\, e^{ikx} + b e^{i2kx} \right|^2$$

$$= a^2 + b^2 + 2R_e \left[a b^* e^{-ikx} \right]$$

P_{meas} multiple carrier input

$$P^{N}_{meas} = \left| \sum_n a_n e^{ik_n x} + b_n e^{i2k_n x} \right|^2$$

$$= \left[\sum_n a_n e^{ik_n x} + b_n e^{i2k_n x} \right] \left[\sum_m a^*_m e^{-ik_m x} + b^*_m e^{-i2k_m x} \right]$$

$$= \sum_n a_n^2 + \sum_n b_n^2 + \sum_{n \neq m} \sum_n a_n a^*_m e^{i(k_n - k_m)X}$$

$$+ \sum_{n \neq m} \sum b_n b^*_m e^{i2(k_n - k_m)X}$$

$$+ \sum_n \sum_m 2R_e \left\{ a_n e^{ik_n x} b^*_m e^{-i2k_m x} \right\}$$

$$\approx \sum_n^N a_n^2 + b_n^2 + 2R_e \left[a_n b_n^* e^{-ik_n x}\right]$$

For Large N

Then the power ratio for single carrier in to spectrum analyzer out

$$\frac{P_{meas}^{(1)}}{P_o^{\,s}} = \frac{a^2 + b^2 + 2\,R_e\,[ab^* e^{-ikx}]}{a^2}$$

$$= 1 + b^2/a^2 + \frac{2}{a^2} R_e\,[ab^* e^{-ikx}]$$

and for multiple carriers in and power meter out

$$\frac{P_{meas}^N}{P_o^{\,M}} \cong \frac{\sum_n^N a_n^2 + b_n^2 + \sum_n^N 2R_e\,[a_n b_n^* e^{-iknX}]}{\sum^N a_n^2}$$

$$\cong 1 + \frac{\sum b_n^2}{\sum a_n^2} \quad \text{for } k_n x,\ N \text{ large}$$

since over N carriers the phase term $-k_n x$ varies quickly through $-\pi$ to π, yielding a small error term.

Thus $$1 - \frac{P_{meas}^N}{P_o^m} \leq 1 - \frac{P_{meas}^1}{P_o^s}$$

improving the accuracy in the presence of 2nd harmonic.

2.8 IMPROVED 200 AND 725 MHz VOLTAGE CONTROLLED OSCILLATOR

The 200 and 725 MHz Voltage Controlled Oscillators along with their associated phase lock-loop functions serve as the Local Oscillators for Frequency Translation of the DSCS Uplink frequencies to the companion downlink frequencies. Therefore, Transponder Communication traffic performance is linked directly to the design characteristics of these VCO's. Past problems encountered with phase transients and satellite reaction wheel effects, have been linked to VCO performance. As a result, the VCO's were targeted as candidates for design improvement. Since considerable effort has been expended over the past years toward improvement of the existing design, the design improvement study was focused on alternate design techniques. The study results defined the best alternate design candidate to be one based on a Surface Acoustic Wave (SAW) delay line. The SAW device approach allows deletion of several potentially troublesome mechanical tuning adjustments and is small enough to be made physically compatible with replacement of the present devices with minimum impact.

2.8.1 DESCRIPTION OF SELECTED APPROACH

2.8.1.1 Electrical Circuit Description

The basic SAW oscillator consists of the following circuits referenced to the VCO block diagram, Figure 2.8-1, and the VCO schematic, Figure 2.8-2. A parts list is provided in Table 2.8-1.

1. A voltage controller phase shifter (C1, C2, C3, CR1, R1, R2, R3).
2. An RF Amplifier Stage (C5, C6, C7, C8, L1, L2, L3, L4, Q1, R4, R5, R6, Y1).
3. A SAW delay line with response at the operating frequency.
4. An isolating buffer RF Amplifier (C9, C10, C11, C12, C13, Q2, R6, R7, R8, R9).
5. An output ferrite isolator identical to that used in the present VCO's.

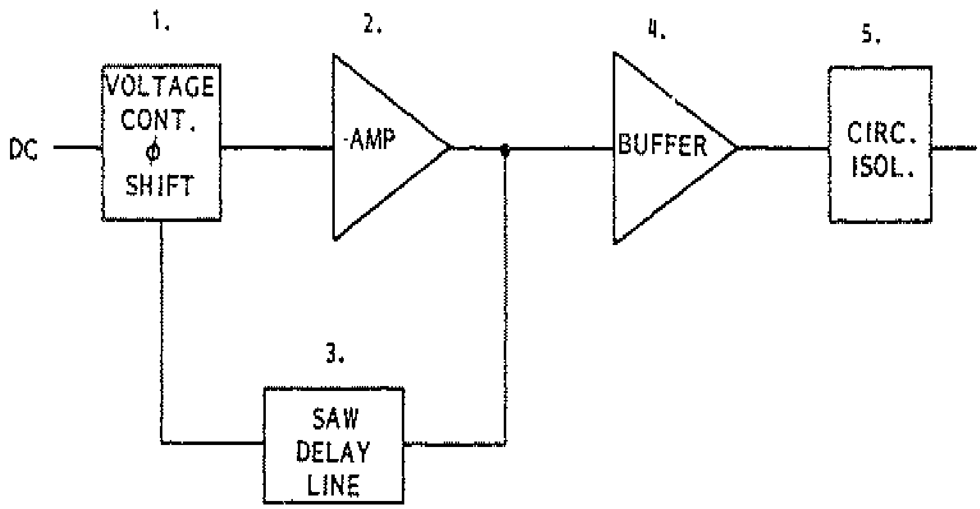


Figure 2.8-1. SAW VCO Block Diagram

The amplifier maintains oscillation by feeding the output through a frequency selective SAW delay line back to the input of the amplifier. The SAW delay line has an input and output filter which prevent feedthrough of signals other than the chosen operating frequency. A signal passing through the SAW device is also delayed by about 1 microsecond. Assuming a delay of .9975 microseconds or 199.5 wavelengths at 200 MHz, the signal out of the delay line would be shifted by 71,820 degrees or 180° out of phase with respect to the input required for oscillation. Changing the delay line input frequency to 200.5 MHz would cause a shift of 72,000 degrees or 180 degrees with respect to the input. It then becomes apparent that the delay line can maintain excellent control over the operating frequency since any drift of frequency represents a large phase change at the output of the SAW. This principle is the same utilized by an cavity or crystal oscillator to maintain the oscillator on a precise frequency.

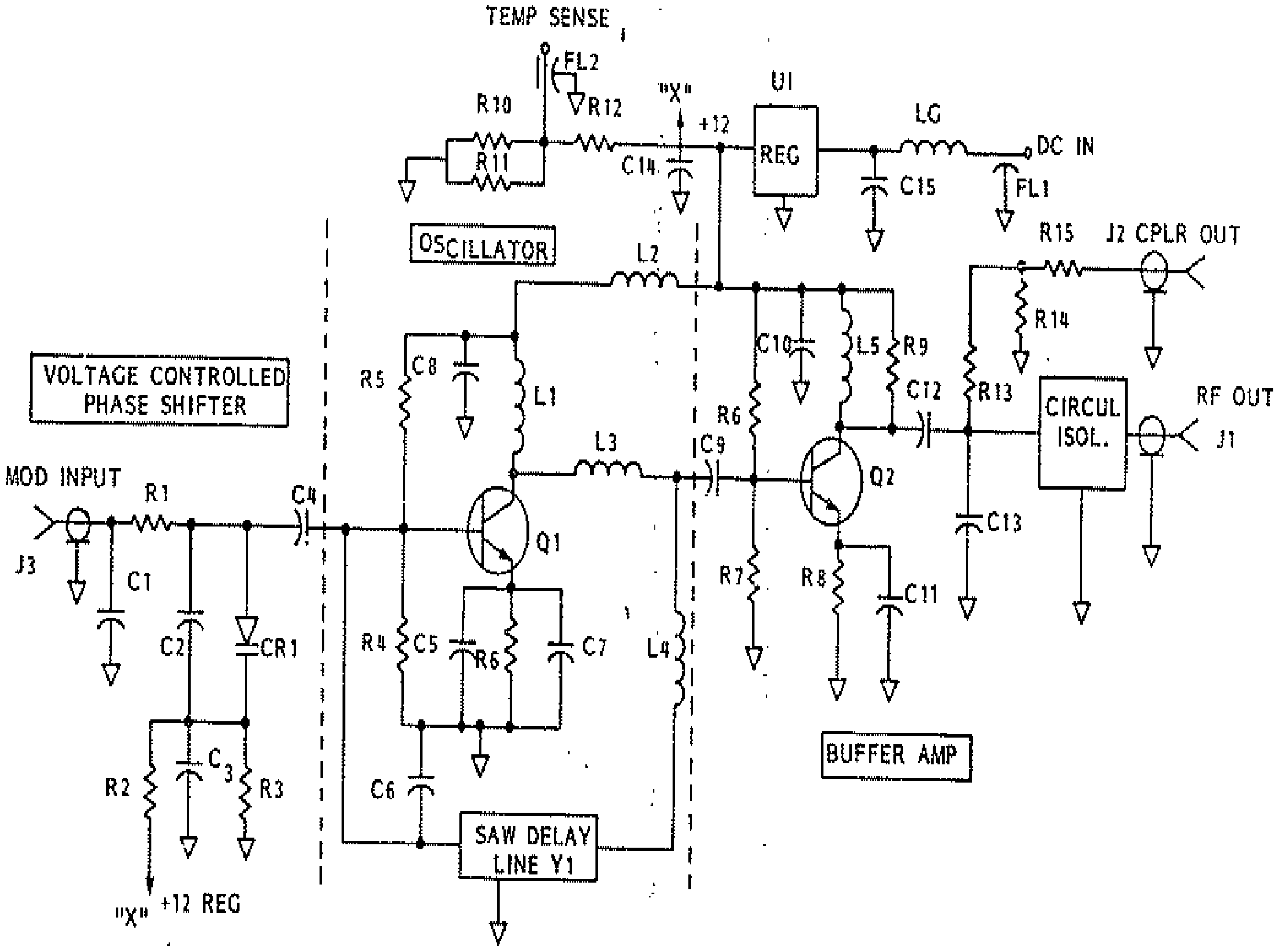


Figure 2.8-2. SAW VCO Schematic

Table 2.8-1. SAW VCO Parts List

Symbol	Description	Part Number	Comments	Total Quantity
C1-C13	Chip Capacitor	R9366PXXX	ATC100B with Strip Leads	13
C14-C15	Capacitor, Tant	MIL-C-39003/01	CSR13 Series	2
CR1	Volt. Variab Cap.	R9833PX	Similar to IN5139	1
FL1	Filter RFI	R4401P2		1
FL2	Feedthru Filter	R4403P1		1
J1-J3	SMA Connect	47B241843P1		3
L1-L6	Molded RF Coils	R4440PX	1025 Series	6
Q1-Q2	RF Transistor	R9756P1	CD3866	2
R1-R9	Resistor, Metal Film	MIL-R-55182/01		9
R10	Thermistor	R4387P1		1
R11-R15	Resistor Metal Film	MIL-R-55182/01		5
U1	Regulator IC	R4883P2	LM120H	1
Y1	SAW Delay Line			1
Isolator	200 MHz 47C242383P1 (725 MHz - 47C242386P1)			1
PC Boards				2
Chassis				1

The delay line approach was selected over a SAW resonator because the frequency of the oscillator can be moved over a larger range with an external control voltage than for the SAW resonator approach. A 1 microsecond SAW delay line VCO can be changed by 1.0 MHz with linear control.

The approximate 1.0 MHz linear control range is smaller than provided in the present 200 MHz and 725 MHz VCO's. The excellent SAW device frequency setability (factory defined SAW operating frequency) plus the -90 ppm temperature stability of the SAW over the DSCS acceptance temperature range of -24° to +61°C makes the reduced frequency pulling range more compatible with long term operation in space than for the present devices. As an example, the thermal stability of the present 725 KHz cavity VCO is on the order of 300 KHz peak to peak for a 3 MHz frequency pulling range or about 414 ppm over the DSCS acceptance temperature range stated above. In short, the 65 KHz SAW VCO temperature stability versus a 1 MHz pulling range is better by close to a factor of two over the 300 KHz versus 3 MHz experienced in the present cavity VCO.

The new tuning range sensitivity required for the SAW VCO is easily accommodated by changing part values on up to five resistors and capacitors in the companion Phase Lock Loop (PLL) printed wiring board (PWB). As a result, all electrical changes are limited to the component level, the Frequency Generator. The Frequency Generator PLL control performance will then be equal to or exceed that experienced with the present VCO's so as to maintain or enhance DSCS communication channel performance. Low frequency interference from the board power supply or other sources will be tracked out or corrected as it is in the present Frequency Generator design. Power Supply modulation and/or ripple rejection for a SAW VCO can be improved over the present designs. The physical size reduction of the SAW elements which defines the oscillator frequency when compared to the present resonating elements allows a design to be implemented with better regulation and RF isolation from the input DC bias lines.

2.8.1.2 Mechanical Design Description

The mounting hole pattern of the VCO will match the present mounting pattern of the 200 MHz and 725 MHz VCO as applicable.

The housing will be machined from Aluminum Alloy 6061-T6. The cover will also be fabricated of aluminum alloy 6061-T6. Both cover and housing will be finished with Alodine 600 per GE Drawing 171A4912 (Type 1). Threaded holes used to mount frequently moved parts or assemblies will make use of steel helicoil inserts. The basic housing design will be a simple rectangular box machined by tape (NC) controlled mills. The inside will be divided into two cavities. The first end section and approximately one-half of the remaining volume will house the isolator and the oscillator buffer Printed Circuit Board. The remaining volume will contain the regulator and filter printed wire board and circuitry. (See the block diagram, Figure 2.8-3, for circuit functions referenced.)

Interconnection between the isolator and the oscillator/buffer circuit board will now be direct. There is no partition (wall) between the isolator and the oscillator. There is a top to bottom wall enclosing the regulator/filter board. Interconnection through this wall to other internal circuitry is accomplished with threaded feedthrough filters.

The coaxial connectors (SMA) will be located in the same relative positions as the original units. This will allow only minor cable changes and allow cable runs to remain essentially the same as before.

The estimated size of both VCO's not including the mounting base is 4.00 inches x 1.75 inches x .875 inches high. The estimated weight of a 200 MHz VCO = .55 lb. The estimated weight of a 725 MHz VCO = .45 lb. This represents essentially no change from the present VCO's.

2.8.2 PERFORMANCE SUMMARY

A performance summary chart is provided in Table 2.8-2. The SAW oscillator change would have no physical impact outside the Frequency Generator. As shown on the charts, Table 2.8-2, DC voltage and power requirements would remain the same. Also, the telemetry output is the same as well as the RF levels.

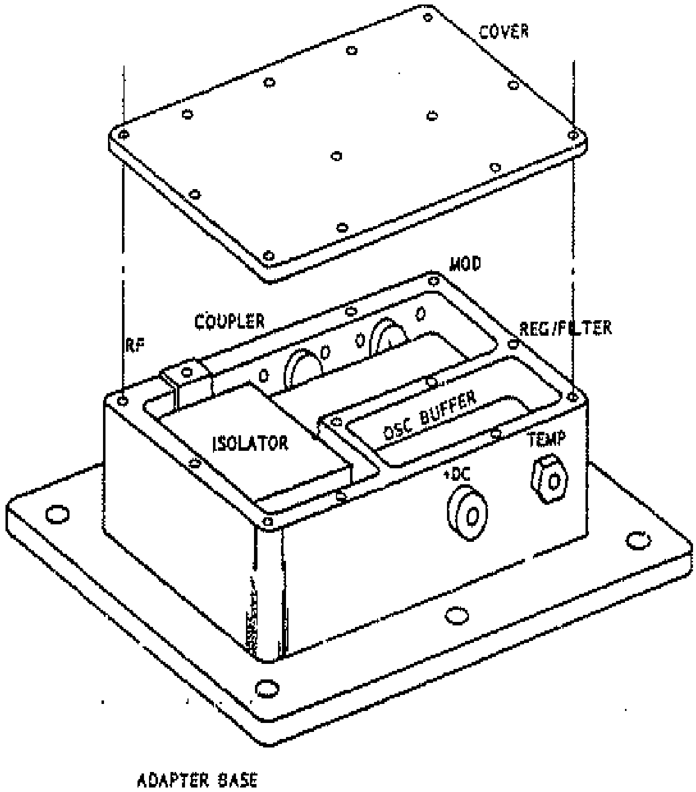


Figure 2.8-3. Typical VCO Mechanical Configuration for the 200 MHz or 725 MHz Units

Narrowband phase noise remains as good as the present VCO while the wideband noise performance is improved markedly.

The tendency for microphonic susceptibility is eliminated since the SAW device does not have this problem.

Harmonic output as well as tolerance to power supply variation will be either improved or not change.

Since the SAW devices have much less drift it was advisable to change the tuning sensitivity. This change can be easily accommodated with value changes in at most 5 capacitor or resistor values in the companion PLL PWB.

Table 2.8-2. Performance Estimate Comparison of SAW VCO's to Present VCO's

Category	Pres. DSCS VCO	SAW VCO	Comments
RF Output	725 MHz = 17.75 dBm 200 MHz = 13 dBm	727 MHz = 17.75 dBm 200 MHz = 13 dBm	No change from DSCS Spec
Tuning Sensitivity	725 MHz 200 KHz/Volt 200 MHz 1 MHz/Volt	100 KHz/Volt	New tuning sensitivities are easily accommodated by changing the values of a maximum of 5 resistor or capacitor values on companion PLL PWB.
Bias Current	725 MHz - 65 MA Max. 200 MHz - 29 MA Max.	725 MHz - 65 MA 200 MHz - 29 MA	No change from DSCS Spec
Volts In	725 MHz - 28 volts 200 MHz - 24 volts	725 MHz - 28 volts 200 MHz - 24 volts	No change from DSCS Spec
Telemetry	Temperature	Temperature	No change from present design
Phase Transient Susceptibility	Mechanical adjustments present	Removal of mechanical tuning predicts reduced susceptibility	Oscillator design is less susceptible to transients due to SAW delay line.
Wideband Phase Noise	Baseline	Superior to pres. VCO	SAW characteristics result in low phase noise design.
Narrowband Phase Noise	-25 dBc .6-75 Hz phase locked	-25 dBc .6-75 Hz phase locked	Same or better than present VCO.
Vibration Suscept.	Susceptible to microphonics	Superior to pres. VCO	Due to the nature of the SAW delay line.
Harmonic Output	-30 dBc	-30 dBc	Meets present DSCS Spec
Toler. to Supply Variation	6 dB margin from degradation by reaction wheel noise	6 dB reaction wheel noise margin	Exceeds present DSCS Spec
Long Term Freq. Stability	50 PPM/Year or 500 PPM 10 Years	10 PPM/Year or 100 PPM for 10 Years	72.5 KHz for 725 MHz SAW Unit 20.0 KHz for 200 MHz SAW Unit

The long term stability of the SAW VCO is improved by at least five to one over the present VCO - this being true because the SAW delay line is a quartz device. Long term stability, temperature effect, frequency stability and other effect on frequency accuracy are summed up in Table 2.8-3. The worst case drift of 200 KHz for the 750 MHz unit compares very favorably with the 1 MHz frequency pulling capability available.

Table 2.8-3. Frequency Variation Table

	PPM	200 MHz	725 MHz
Temperature (-34 to +71)*	-150 PPM	-30 KHz	-108.75 KHz
Set Accuracy	+/- 20 PPM	+/- 4 KHz	+/-14.5 KHz
SAW Aging (10 years)	+/-100 PPM	+/-20 KHz	+/-72.5 KHz
Temp. Variat. of Circuit	+/- 10 PPM	+/- 2 KHz	+/- 7.25 KHz
Aging of Circuit Comp.	+/- 5 PPM	+/- 1 KHz	+/- 3.62 KHz
Freq. Pulling	+/- 10 PPM	+/- 2 KHz	+/- 7.25 KHz
Power Supply Drift	+/- 10 PPM	+/- 2 KHz	+/- 7.25 KHz
Total Worst Case Drift	-305 PPM	-61 KHz	-221.12 KHz

*A temperature stability curve is given in Figure 3.8-3, which shows a -90 PPM characteristic over the -24 degree C to +61 degree C acceptance temperature range and less than -30 PPM change for the on orbit Frequency Generator operating temperature range.

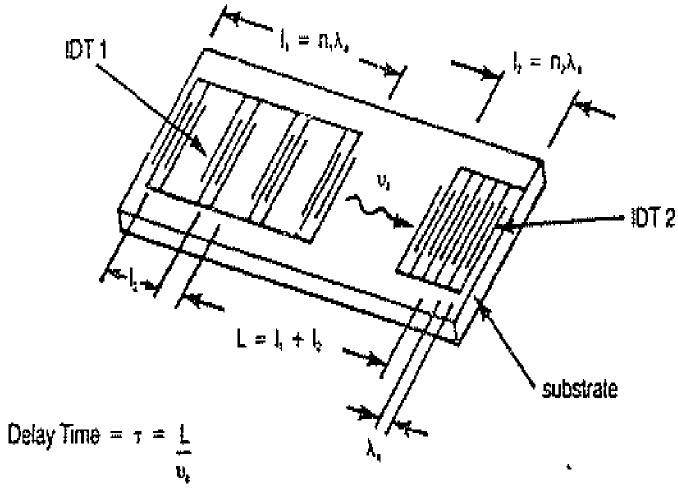
The SAW VCO has greatly improved immunity to conducted EMI for two reasons - the first being the priorities of the SAW device oscillator and the second being the space allowed for better shielding and filtering due to the much reduced size of the SAW device compared to the cavity.

2.8.3 BENEFITS OF SELECTED APPROACH

A SAW VCO has inherent advantages in electrical performance over the present approaches as defined by reduced phase noise, a more predictable aging characteristic to frequency stability, and a reduced susceptibility to EMI. The discussion on advantages will be aided by the following short tutorial on SAW VCO operating principles.

The SAW VCO operating frequency is defined by a Surface Acoustic Wave delay line as shown in the feedback loop of the VCO block diagram, Figure 2.8-1. The delay line design parameters are then detailed in Figure 2.8-4. As shown in this figure, electrodes or finger elements are used to form the interdigital transducer (IDT's) which launch and receive the surface acoustic waves (SAW's). The operating frequency of the SAW transducer is determined by the physical spacing (λa) of the individual elements. The frequency timing range of the oscillator is related to the delay time (τ) which is determined by the spacing (L) between IDT's. Therefore, the delay time is fixed by design and is constant with frequency over the delay line passband.

The SAW VCO tuning range is the frequency range over which the oscillator can be pulled. The available tuning range is governed by the bandwidth of the SAW delay line which = 1/SAW delay = $1/\tau$. In order to insure linear and stable tuning, the central 50% of the bandwidth is used or $1/2\tau$. A practical lower limit for SAW delay is 500 nsec., which yields a maximum 1 MHz tuning range. Figure 2.8-5 shows the tuning characteristics of a VCO utilizing an 830 nsec. delay line with an available passband of 1.2 MHz. As can be seen, good tuning linearity is maintained with an average tuning sensitivity ($\Delta f/\Delta y$) for the SAW VCO of 77 KHz per volt. The typical RF power output variation based on test data from Anderson Labs devices over the entire tuning range depicted in Figure 2.8-5 is on the order of 0.8 dB.



τ = delay time
v_s = acoustic velocity
λ_s = acoustic wavelength
$= \frac{\text{acoustic velocity}}{\text{desired frequency}} = \frac{v_s}{f_0}$

L = center line distance between IDT's
n_1, n_2 = integers

Figure 2.8-4. Illustration of SAW Delay Line

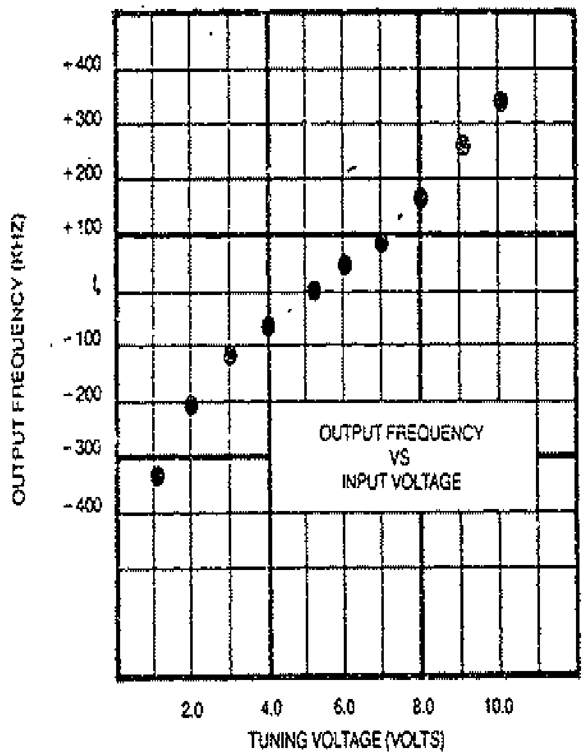


Figure 2.8-5. Frequency vs. Tuning Voltage for SAW VCO with 830 nsec Delay Line

Frequency satability and temperature stability problems encountered in early SAW devices have been solved. Substrate manufacturing processes have been improved to where the λ_a finger spacings in Figure 2.8-4 can be assigned accurately enough to define the initial operating frequency at 25°C within $\pm$20 ppm of the desired frequency. The use of temperature stable quartz for the SAW substrate provides the frequency stability versus temperature characteristic of Figure 2.8-6. This characteristic, when related to the SAW frequency range of 1 MHz ano then compared to the present cavity VCO frequency stability versus its pulling range defines an approximate factor of two advantage for the the SAW based VCO; i.e., 65 KHz to a 1 MHz tuning range for a SAW VCO versus 300 KHz to a 3 MHz tuning range for the present cavity VCO as discussed in Section 2.8.1.

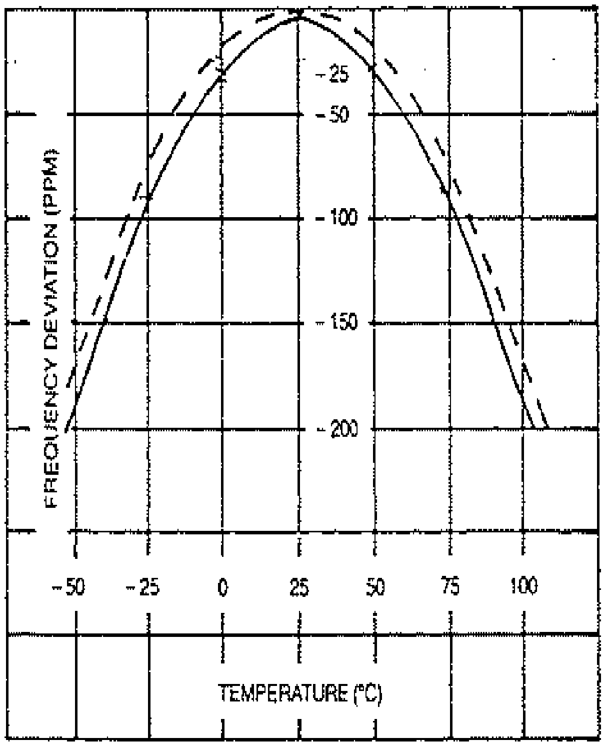


Figure. 2.8-6. Typical Frequency vs. Temperature Characteristics

Although the phase noise characteristic of the present VCO's is compatible with satellite operational needs, the higher Q and therefore lower phase noise SAW based VCO's do increase the margin against communication channel performance degradation. However, the main benefit to a user should derive from the ability to delete critical mechanical tuning adjustments from the VCO design. The present 725 MHz VCO cavity design requires the use of a mechanically tunable capacitor plus two cavity tuning screws to achieve the proper degree of frequency setability. The tunable capacitor setting, in particular, has a large enough effect on the oscillator frequency that mechanical stress built up during the tuning operation must be relieved by a temperature cycling operation. Each VCO is temperature cycled to relieve mechanical stress until a frequency drift rate is achieved that is compatible with a 10 year operation in space. An estimate of frequency stability based on the temperature cycle data extrapolated to the temperature environment experienced in space is on the order to 50 ppm/year. The SAW oscillator, on the other hand, has no critical frequency setting adjustments. The VCO operating frequency, instead, is defined as cited earlier, by the transducer finger spacing accuracy achieved during manufacture of the SAW substrate. The initial frequency definition accuracy as given above is 20 ppm. Data on aging acquired to date indicates that an assignment of 10 ppm/year can be conservatively made. A study conducted by Raytheon from 1976 to 1983 as reported at the 1983 Ultrasonics Symposium, "Random and Systematic Contributions to Long Term Frequency Stability in SAW Oscillators", by T.E. Parker showed stability results of 6 ppm per year for earlier devices and 2.4 ppm per year for later SAW devices mounted in improved packages. Table 2.9-3 of Section 2.8.2 shows that the SAW VCO design can tolerate far more drift than even the conservative 10 ppm year assignment. The principle point to be made, as stated, earlier, is that the SAW VCO design allows several mechanical frequency adjustments to be removed from a critical local oscillator (LO) function required for frequency translation in the DSCS satellite transponder. Removal of these adjustments will enhance the

reliability of the LO's and improve the predictability of VCO frequency stability and thereby reduce the phase lock loop tuning control range required to keep the LO locked to the satellite 5 MHz standard.

A second major advantage achievable from a SAW VCO is the ability to improve EMI performance, particularly a reduction in the susceptability to conducted audio interference on the DC bias lines. The small size of the SAW delay line plus the ability to operate at lower voltages will allow the VCO design to be optimized for rejection of conducted interference while maintaining improved RF isolation between the oscillator and its bias circuitry. As a result, greater margin can be achieved against communication channel degradation from satellite based interfering sources such as the reaction wheels.

The present VCO designs are difficult to build and test. The cavity VCO, because of some critical mechanical timing adjustments required extensive temperature cycling to assure removal of mechanical stresses. As a result, the net schedule commitment required to build and test each VCO usually makes it the -limiting item in an RF component buildup. The Frequency Generator representing an important element of DSCS North Panel assembly could benefit greatly from a test schedule simplification associated with replacement of its VCO's with mechanically compatible SAW VCO subassemblies. The SAW VCO, requiring no critical mechanical tuning adjustments, will not have to be subjected to the thermal cycling stabilization test. Its aging characteristics, despite the test simplification, will be far more predictable than that of the present VCO's.

2.8.4 IMPACT OF SELECTED APPROACH

Replacement of the present Frequency Generator 200 MHz and 725 MHz VCO's with SAW VCO designs will have no impact on any other component or function on the DSCS satellite. The only telemetry function directly associated with the present VCO's is a temperature monitor. This temperature monitor will be replaced in the SAW VCO with an essentially identical thermistor based resistor network.

The SAW VCO bias voltages requirements will be kept identical to those required for the present VCO's. Since the SAW VCO bias currents will be equal to or less than the present requirements, no North Panel Power Controller (NPPC) changes will be required. The SAW VCO's will be provided with linear series regulators to isolate the oscillators from the line drops associated with RC filtering incorporated in the NPPC and Frequency Generator.

The SAW delay line, which defines the associated VCO frequency, is physically very small. As a result, the replacement VCO's can be made physically interchangeable with the present VCO chassis. The only component level design effect will be some slight changes in RF coaxial line and bias wire lengths and routing. The mechanical design discussion in Section 2.8.1 gives a rationale for how the SAW VCO's are accommodated with no effect on the present frequency generator chassis design and minimal effect on interwiring.

All other interfaces with the Frequency Generator remain unaffected by SAW VCO replacements. The SAW VCO designs will be defined so as to duplicate the present RF power outputs. Therefore, all RF and 5 MHz standard distribution levels will remain the same as they are now because no changes will be required in the associated distribution PWB's.

2.8.5 RISKS OF SELECTED APPROACH

The circuitry shown in the schematic, figure 2.8-2, is very similar to SAW oscillators being produced commercially. SAW oscillators are produced in high volume for the commercial and consumer markets. The military market also utilizes them extensively. There has been no application yet to satellites that we are aware of but vendors are preparing to deliver space qualified SAW devices.

A main point of concern may be the expected aging performance in space. Studies that define the aging mechanisms have been identified and numerous accelerated aging tests at high temperatures have been conducted. A design

allowing a 10 ppm drift per year for 10 years yielding a 100 ppm total is regarded by vendors as extremely safe. (See discussion in Section 2.8.3 where test results are referenced which show 6 ppm and 2.4 ppm per year.)

Since SAW devices are constructed using quartz, a great deal is known about the basic material. Quartz crystals are used in frequency generators aboard numerous spacecraft. No particular difficulties have arisen from the use of quartz. Mechanical and electrical aging qualities are well known. The SAW delay line utilizes many of the same methods and materials in construction as the familiar quartz crystals.

The small physical size of the SAW elements allow a VCO to be designed which is physically and electrically interchangeable with the present VCO's. Since all changes are limited to the Frequency Generator, the changes, if properly planned, can be incorporated with negligible effect on satellite assembly and test schedules.

SAW device qualification can be accomplished via a combination of special vendor testing plus protoflight level testing of the first production Frequency Generator containing the SAW VCO upgrades.

2.8.6 RATIONALE FOR THE SELECTED APPROACH

The Frequency Generator VCO's and associated PLL PWB's provide satellite Frequency Standard derived Local Oscillator (LO) signals for translating the DSCS uplink signals from the 7.9 to 8.4 GHz band to the downlink compatible 7.2 to 7.7 GHz band. As a result, the communication channel traffic integrity can be affected by the RF characteristics of these LO's. To prevent this occurrence, the Frequency Generator or its VCO's are tested for compliance in phase noise characteristics, for absence of phase transients for sufficient suppression of bias line conducted interference, and for stable RF power output levels. Good long term frequency stability of the VCO's is also required in order to assure maintenance of phase lock to the satellite frequency standards over a ten year life goal. The necessary use of

mechanically tunable capacitors for fine and course frequency control makes it necessary to temperature cycle each cavity VCO in order to reduce mechanical stress effects and thereby meet the long term stability predictions.

As stated in Section 2.8.3, the present DSCS VCO designs are difficult to build and test. Each 200 and 725 MHz VCO presently goes through a complex select-by-test part selection process during module test in order to meet voltage tuning performance requirements. The positioning of the select-by-test parts must be done carefully in order to prevent potential in-band spurious resonances from modifying the voltage tuning linearity.

Based on the above discussion, the Frequency Generator VCO design rationale has to be based on achieving additional communication channel performance margin plus correcting the manufacturing difficulties associated with the present designs. Therefore, a new VCO design approach for this component should meet or exceed the present specifications while deleting VCO based critical mechanical frequency control adjustments. Also, because of past problems with rejection of satellite level reaction wheel noise, a new design approach should provide for additional design margin against re-occurrence of the problem. The key design parameters can be summarized as follows:

1. Meet or exceed the present phase noise characteristics.
2. Decrease susceptibility to phase transient occurrences via removal of as many mechanical frequency control elements as possible.
3. Improve long term stability predictability.
4. Improve manufacturability and testability.
5. Improve margin for rejection of bias voltage noise from sources such as the reaction wheels.
6. Delete need for thermal cycle frequency stabilization test.
7. Implementation of redesign to be accomplished with no impact on any other satellite component and be mechanically configurable for use in the present Frequency Generator component chassis.

The above listed criteria were used to investigate feasibility of the approaches defined in Table 2.8-4.

Table 2.8-4. Design Tradeoff Table

Approach	Comments
Dielectric Resonator VCO	Resonator size too large at 725 MHz and larger at 200 MHz.
Crystal Oscillator plus Multiplier	Overly complex and incompatible with present DC voltage and power requirements.
SAW Resonator Based VCO	Marginal tuning range when compared to best achievable temperature stability.
SAW Delay Line Based VCO	Tuning range compatible with projected thermal and long term frequency stabilities. Size and DC power requirements also compatible with use in present Frequency Generator with minimum impact.

As shown in Table 2.8-4, the best approach for this application is a SAW delay line based VCO. The SAW device is small (can be packaged in a TO8 size for PWB use) so that an oscillator plus a buffer amplifier can be packaged in an outline matching the present 200 MHz VCO. The circuitry can also be configured for shield isolation between the DC regulator and other bias circuit and the RF circuits. The improved DC to RF isolation will aid optimization for rejection of conducted bias interference.

An important advantage of a SAW based design is derived from the VCO operating frequency being defined by electrode finger spacing on the substrate as explained in Section 2.8.3. As a result, no critical mechanical tuning

elements will be required. Removal of these tuning elements should then allow deletion of the presently required temperature cycling operation for frequency stabilization.

The frequency stability and the frequency variation with temperature are completely compatible with the Frequency Generator application. The conservative 10 ppm per year aging assignment for frequency stability is also compatible with the approximate tuning range of 1 MHz for a SAW delay line based VCO design. The various contributions of frequency error are given in Table 2.8-3. The worst case drift of about 221 KHz when compared to a 1 MHz frequency pulling range provide more than adequate design margin for space use.

2.8.7 SAW VCO DEVELOPMENT SCHEDULE

Figure 2.8-7 gives a development schedule for inclusion of SAW VCO's into the Frequency Generator. The schedule is based on a Protoflight approach to verification of design readiness for flight. Special environmental tests are planned during the breadboard and Engineering models' development stages.

A six month period after CDR is assumed adequate for procurement of Prime SAW VCO parts which will be paced by the SAW delay lines. With modest risk, the advanced order could be placed earlier, if necessary. Manufacturing planning and testing upgrades as required will be workable during the same six time frame so as to be ready for fabrication of the protoflight VCO's as soon as the associated parts are received. The fabrication of the Protoflight Frequency Generator (FG) can be started earlier as the only modules that will be changed are the VCO's themselves. Also, the new VCO's will be designed for mechanical mounting compatibility with the present RF chassis which gives assurance that no parts other than those involved with the VCO's will affect production fabrication. A month and a half period has been set aside for component protoflight testing. The testing of this unit will be shared between Engineering and Quality Assurance. Engineering will perform all functional tests and Quality Assurance will provide environmental test support.

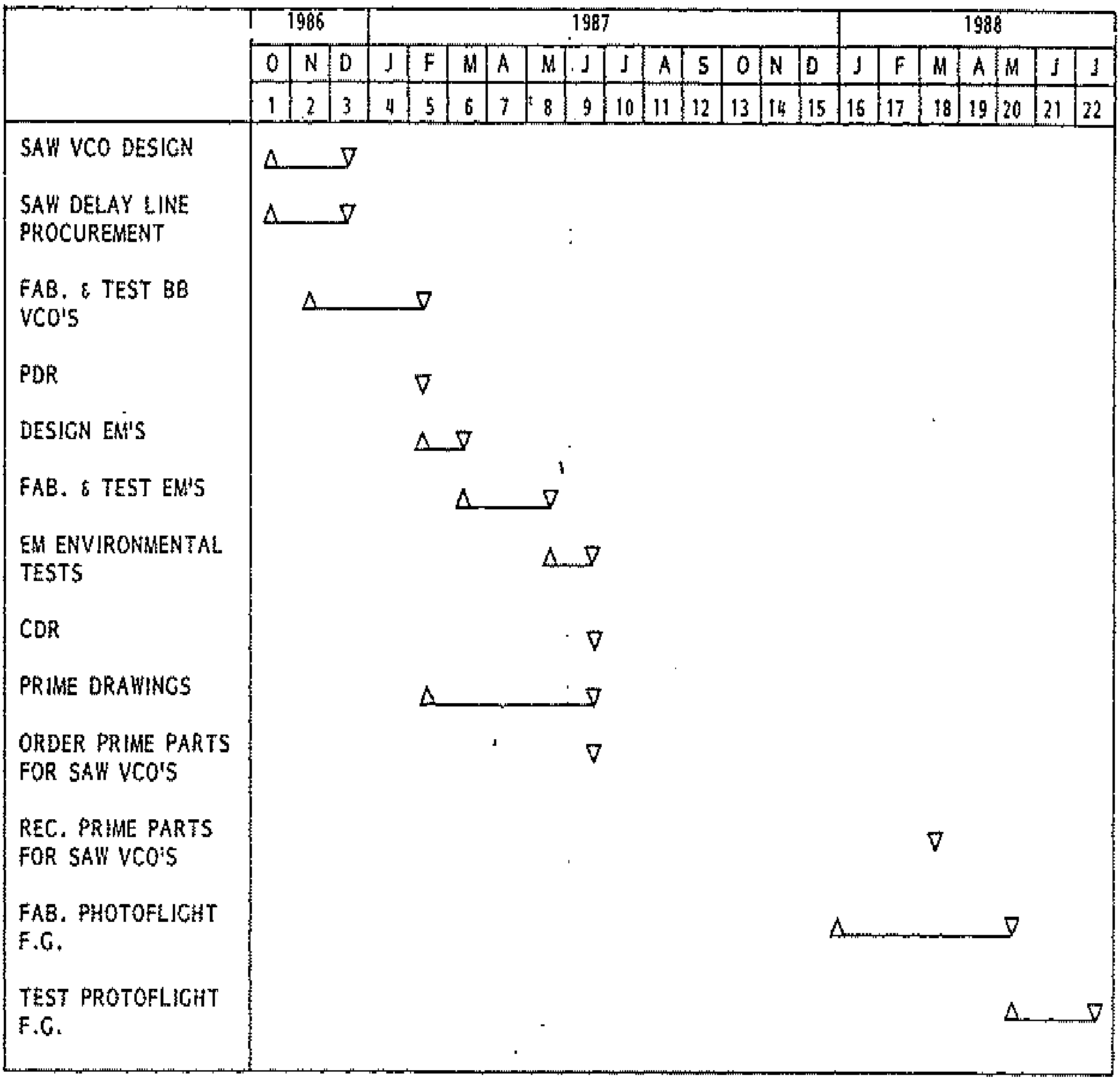


Figure 2.8-7. Development Schedule for Frequency Generator Upgrade with SAW VCO's

2.8.8 RETROFIT OPTION

As indicated by the schedule as defined in Section 2.8.7, the SAW VCO development schedule and subsequent manufacturing delay required for parts ordering makes an upgrade implementation unlikely before 814. However, retrofit of the 812 and 814 satellites may be workable with nominal retesting. Other satellites would required North Panel retesting and satellite level retesting as applicable.

As described in Section 2.8.7, protoflight level testing of the first upgraded Frequency Generator plus special environmental testing at the SAW VCO level is expected to fulfill the qualification requirements for the new Frequency Generator.

Military Uses of Space: 1946-1991

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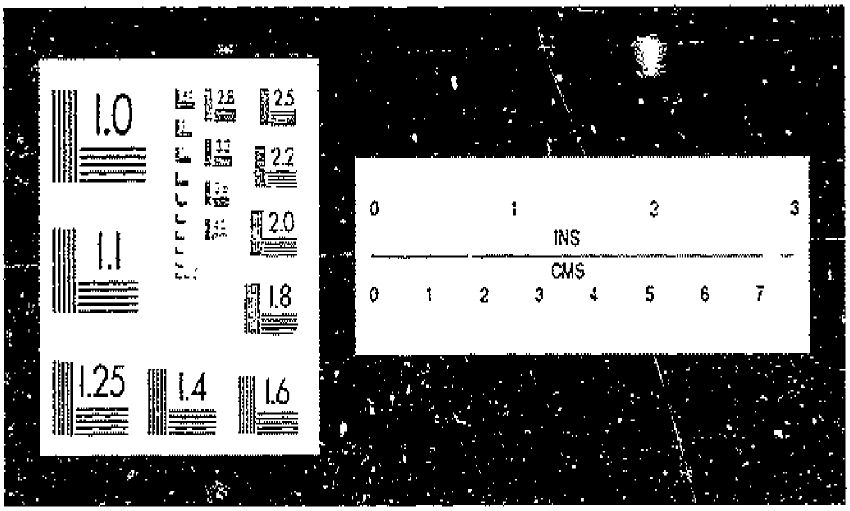

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SECTION 3

OPTION PACKAGES - SYSTEM AND SUBSYSTEM CONSIDERATIONS

SECTION 3

OPTION PACKAGES - SYSTEM AND SUBSYSTEM CONSIDERATIONS

3.1 SHF IMPROVEMENT CONCEPTS SUMMARY

Table 3-1 lists the SHF enhancement concepts studied under the Special Study Task XX (SHF Enhancements). Table 3-2 summarizes the features of these concepts, including the availability of each component. The detailed component description and trade-off analysis for each concept has been discussed previously.

3.2 DEVELOPMENT OF OPTION PACKAGES

This section discusses upgrade options using concepts listed in Section 3.1, or combinations thereof, which have minimal impact to the weight and power consumption of the spacecraft.

Table 3-1. Improvement Concepts

A. Additional Gimballed Dish Antenna (GDA).

B. Multi-mode Earth Coverage Horn (ECH).

C. Steerable hemisphere coverage horn.

D. Removal of one transmit multi-beam antenna (MBX) in combination with concepts a, b and c.

E. Variable RF power splitter between the GDA and MBX in channel two.

F. Ultra-linear solid state amplifier for ten watt channels.

G. Linearizing device for all channels.

H. Transmit level sensor (TLS) accuracy improvement.

I. Improved 200 MHz and 725 MHz voltage controlled oscillator.

Table 3-2. Summary of Concepts

Concept	Description	S/C Δ Wt Lbs	Δ PWR Watts	Availability	Discussion Para.
A	Additional GDA	30.7	None	B14	2.1 and 3.2.1
B	Multi-mode ECH	8	None	B14	2.2
C	Steerable Hemi-sphere Horn	10.3	None	B14	2.3
D	Remove MIX, add A + B + C	-15.5	None	B14	2.1 and 3.2.1
F	Ultra-linear SSA	None	None*	B14	2.5
G	Linearizing Device	5	5.6 watts	B14	2.6
H	TLS Improvement	None	None	B14	2.7
I	VCO Improvements	None	None	B13/B14	2.8

*Power Consumption tailored to power availability

3.2.1 COMMUNICATION SUBSYSTEM CONSIDERATIONS

3.2.1.1 Option Package (A) - Additional GDA

The addition of a second GDA to serve Channel 2 requires an additional FL8-2 output filter, as well as a modification to the ferrite switch, C15-2T. Modification to the switch includes the addition of a VPD (Variable Power Divider) allowing Channel 2 to transmit through both GDA's simultaneously with variable EIRP from each antenna.

Two options that have been considered in the C15-2T switch modification are shown in Figures 3-1A and 3-1B. The simpler option shown in Figure 3-1A consists of simply adding a VPD to the GDA output port of an unmodified C15-2T.

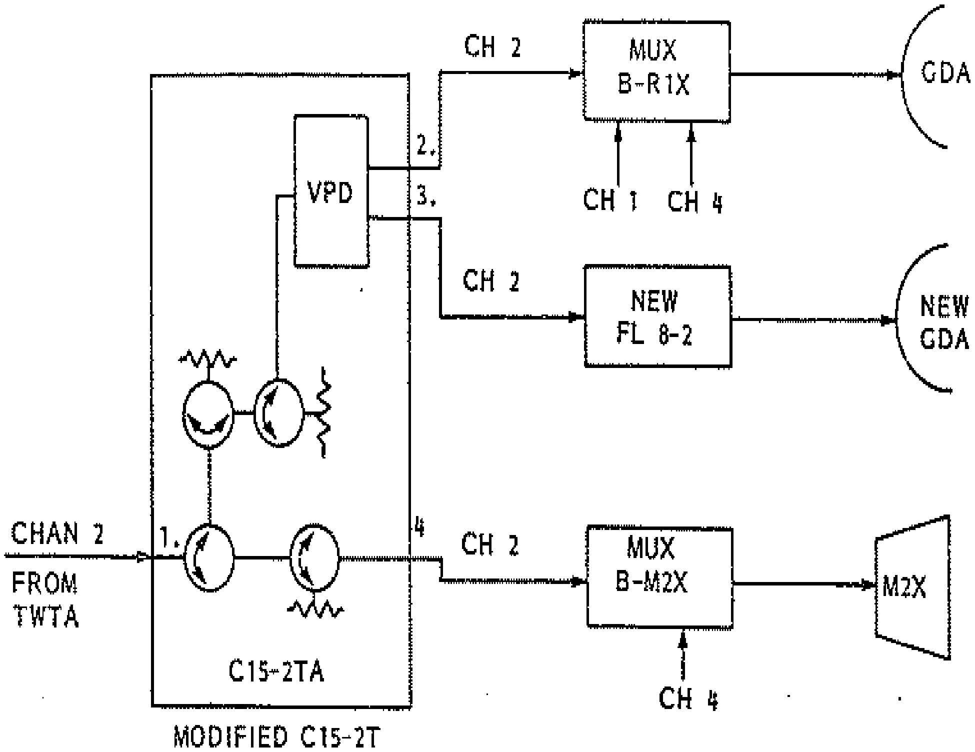


Figure 3-1A. Option Package A - Additional GDA

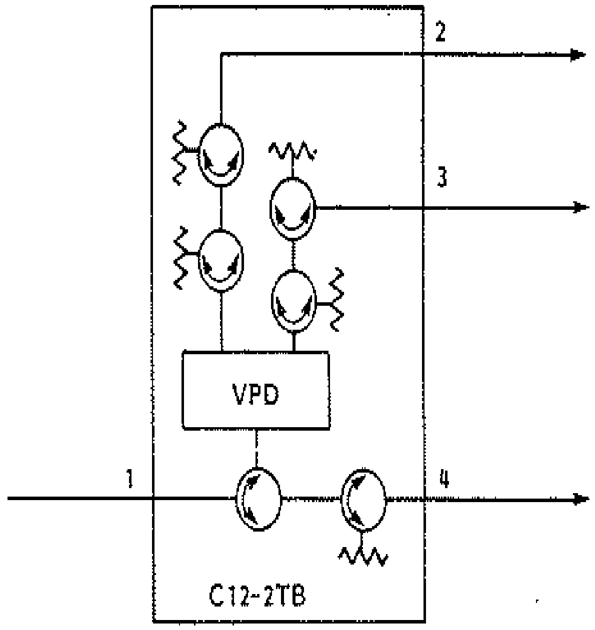


Figure 3-1B. Modified Version of C15-2T Not Selected

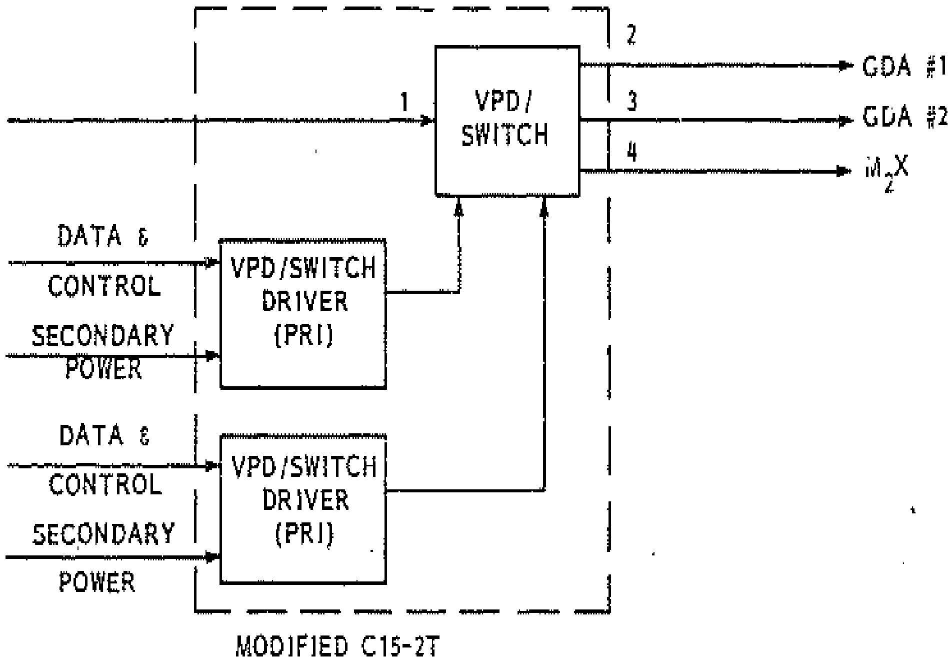
switch to form two GDA variable output ports. A minor disadvantage of this technique is that should it be desired to shut off Channel 2 through one of the GDA's, the typical isolation that can be achieved between the "On" GDA to the "Off" GDA is only about 25 dB, while the isolation using the approach shown in Figure 3-1A is typically greater than 66 dB between main lobes of the two GDA antennas. A trade-off of these two switch options is shown in Table 3-3 below.

The Figure 3-1A configuration is selected because of the lighter weight, less loss, and less repackaging impact. The achievable isolation is sufficient since isolation is the same for either configuratin when both GDA's are used simultaneously, which is the ultimate purpose of this option.

Figure 3-2 shows the interface diagrams of the modified C15-2T switch along with a control table showing the various modes of operation and the commands required for 3-bit control of the VPD.

Table 3-3. Channel 2 Antenna Switch Options

	Figure 3-1A Option	Figure 3-1B Option
Min Isolation, Input to GDA	25 dB	>80 dB
Min Isolation, Input to MBX	43 dB	43 dB
Min Isolation, Input to either GDA when MBX is On	69 dB	69 dB
Typical Insertion Loss, Input to GDA	.47 dB	.48 dB
Typical Insertion Loss, Input to MBX	.15 dB	.15 dB
Estimated Weight	3.7 lbs	3.9 lbs
Size (inches)	5.2 x 4.3 x 11.4	same



CONTROL TABLE

INPUT SWITCH	COMMANDS VPD	RELATIVE SWITCH LOSSES (dB) GDA #1	GDA #2	M_2X
M2X ON	100	69	69	0
M2X OFF	001	0	25	43
	010	1	6.87	43
	011	2	4.33	43
	100	3	3	43
	101	4.33	2	43
	110	6.87	1	43
	111	25	0	43

Figure 3-2. Modified Switch Command Interface

The VPD will be similar to the VPC presently used in Channel 1 for the SCT-SHF downlink. The VPD will not be redundant, just as the present C15-2T switch is not redundant. However, the VPD and switch driver circuit will be redundant, each receiving digital data, control signals, and DC power from a control electronic unit located in the NPPC (North Panel Power Controller). A 3-bit control is tentatively selected for VPD control, providing 7 levels of power ajdustment as shown in Figure 3-2. The present VPC utilizes 6-bit control for 63 levels of adjustment.

Performance/Requirements Summary

- Performance

  The additional GDA adds more flexible capability to Channel 2. Previously, multiple spot beams could only be achieved with the M2X antenna when Channel 4 users (GMF, TACIES, WHCH) had no objections. This capability remaind unchanged. With a second GDA, however, Channel 2 has the sole use of a spot beam with 44 dBW EIRP. Table 3-4 summarizes the Channel 2 performance when both GDA's are used.

Table 3-4. Channel 2 Single Carrier EIRP, dBW

VPD CMD #	GDA #1 EIRP	GDA #2 EIRP
1	44	<19
2	43	37.13
3	42	39.67
4	41	41
5	39.67	42
6	37.13	43
7	<19	44

- Requirements

  The following list identifies design changes necessary to implement the additional GDA as depicted in Figure 3-1A.

  1. Additional GDA

  2. Additional FL8-2 Output Filter

  3. New C1S-2T Modified Switch (with VPD)

  4. Additional Commands for Two GDA's

  5. Additional Commands for VPD Settings

  6. Additional TLM

- Operational Constraint

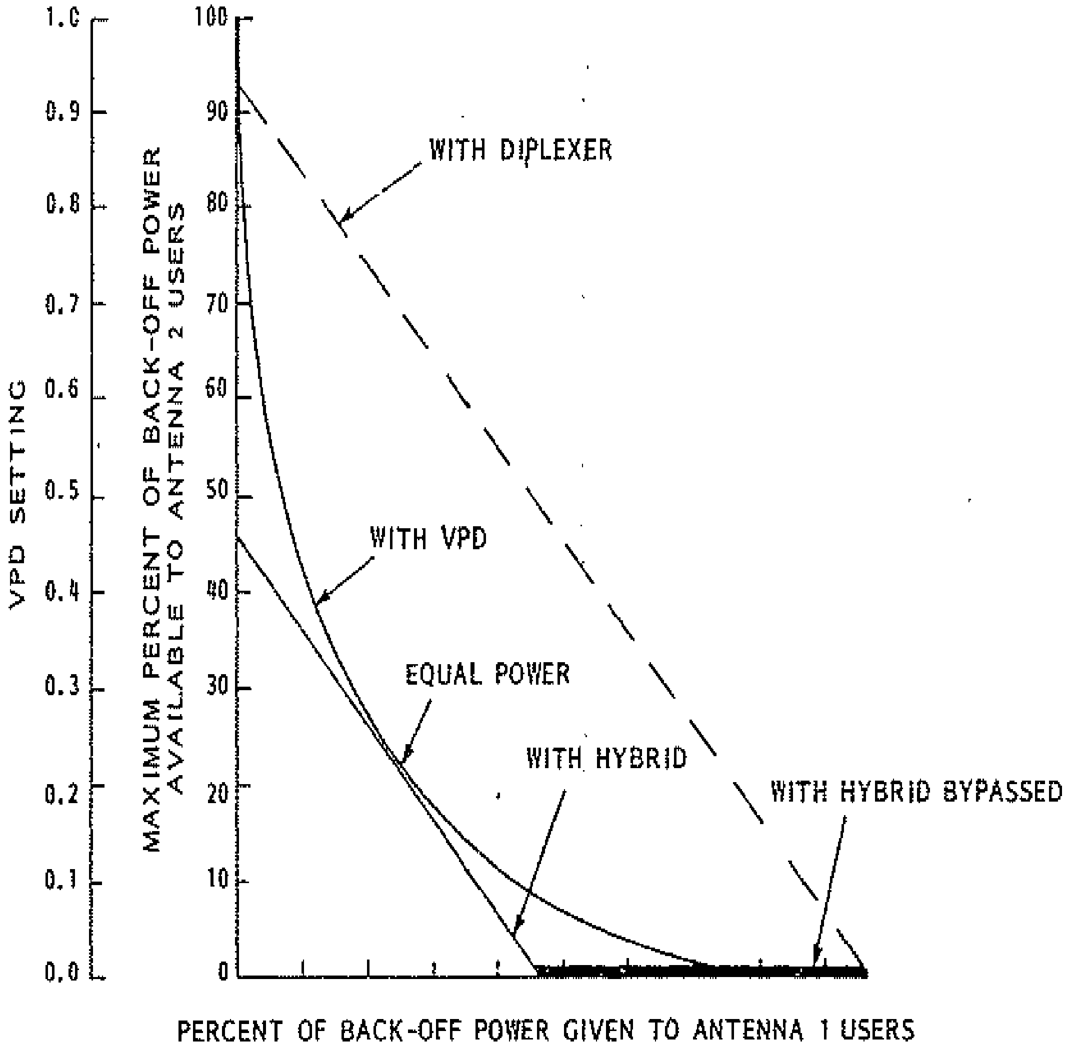
  Antenna targeting must maintain 2 to 3 beamwidth separation to reduce interferometer effect.

3.2.1.2 Additional GDA with VPD Alternatives

Table 3-4 shows the division of downlink EIRP through the two GDA's when the downlink signal is a single modulated carrier. With multiple signals the EIRP is slightly less than shown because of the generation of inband and out-of-band intermodulation products.

With multiple users and with each GDA sharing the downlink power equally, the effective loss instead of 3 dB is 6 dB. This is because the VPD is not selective, and it divides the power equally between GDA's, 25 percent of which includes the correct users and 25 percent, the wrong users. A simple passive hybrid would accomplish the same result. This is illustrated in Figure 3-2A.

The adjustment of useful downlink power using the hybrid is accomplished by varying the uplink power. The adjustments of useful downlink power using the VPD is accomplished by both varying the uplink power and the VPD setting.



- FOR EQUAL POWER TO EACH GDA
  - LOSS = 3.25 dB (APPROXIMATELY 20 WATTS)
  - 23.75% EFFECTIVE POWER (10 WATTS) TO EACH GDA
  - 0.25-dB LOSS WHEN 1 GDA USED

Figure 3-2A. Percent Power to Antenna 2 Users vs. Percent Power to Antenna 1 Users

WP1197/817-280/LR

The maximum available power with the hybrid is only half of that available with the VPD since the hybrid always divides the power by two. For full power to one of the GDA's, the hybrid can be bypassed as shown in Figure 3-2B.

Thus with some reduced flexibility a passive hybrid may be used to perform reasonable power division with greater reliability than the VPD.

For considerably improved EIRP performance, it is recommended that a diplexer approach as shown in Figure 3-2C be studied. This approach requires that each GDA be channelized to one half the Channel 2 bandwidth in the power sharing mode. This should not be a disadvantage since the Channel 2 downlink is power limited, not bandwidth limited. For the case where the full bandwidth is desired through GDA #1, the diplexer can be bypassed as shown.

Another potential advantage of this technique is that since each GDA operates over a different frequency band, the interferometer effect of two closely spaced beams is not as severe as with the VPD.

This technique requires further study to characterize the diplexer and system requirements.

3.2.1.3 <u>Option Package (D) Removal of One MBX Antenna, etc.</u>

This option consists of removing MIX and replacing it with a light-weight steerable hemispheric coverage antenna, and adding an additional GDA as well as replacing the earth coverage horns with multi-mode earth coverage horns which provide more efficient earth coverage. The configuration for this option is shown in Figure 3-3.

The modified C15-2T switch is identical to the one discussed for Option A in Section 3.2.1.1. The VPD allows seven levels of power adjustment between the two GDA antennas.

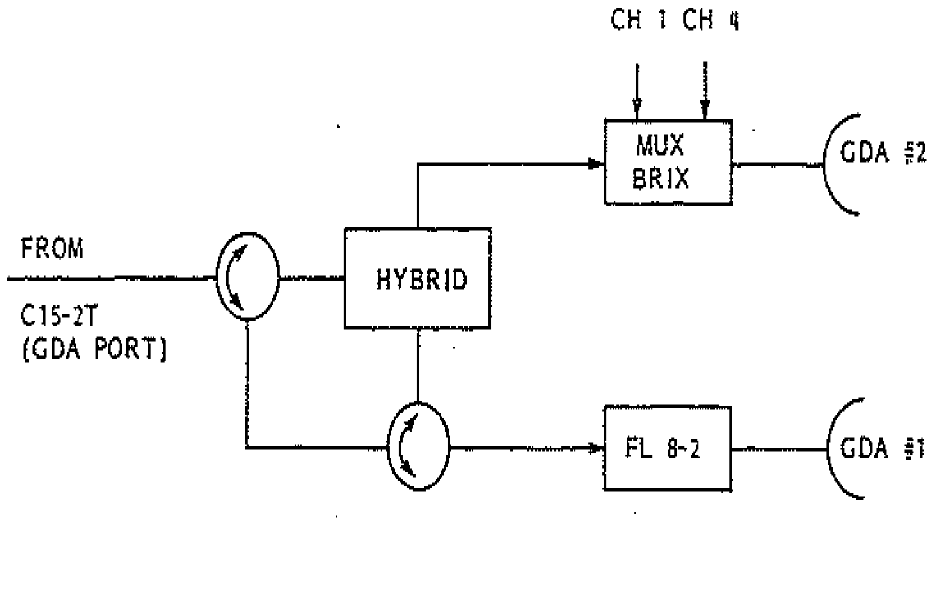


Figure 3-2B. Hybrid Power Divider

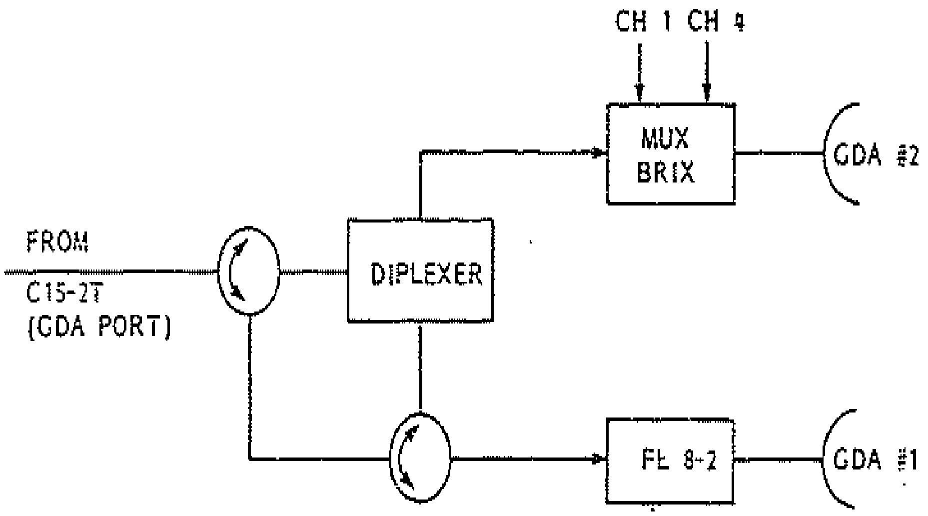


Figure 3-2C. Diplexer Approach

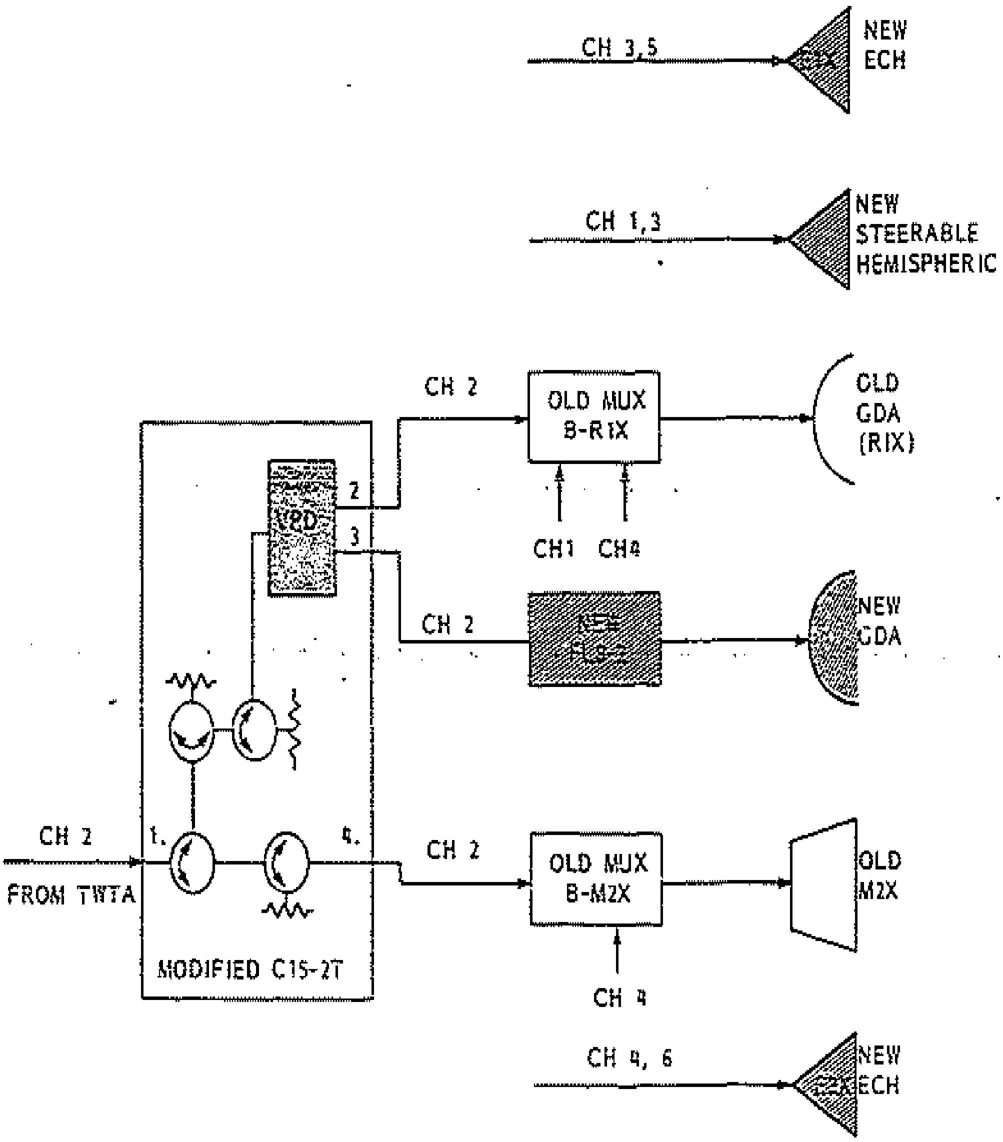


Figure 3-3. Option Package D

The advantage of 2 GDA's for Channel 2 includes more flexibility because of one GDA being dedicated for Channel 2 users only. Two GDA's allow greater EIRP for two simultaneous downlinks, (see Option A). The improved multi-mode earth coverage horns provide more efficient downlink coverage in terms of greater EIRP at edge of earth and for more populated areas.

Table 3-5 summarizes the benefits and impacts to the Users, Spacecraft and the SCCE.

Table 3-5. Option D - Benefits/Impacts

	Benefits	Impacts
User:	• More flexibility for Channel 2 users. More EIRP available for 2 downlinks on Channel 2. • More efficient (EIRP) coverage for Channel 3, 4, 5, 6 users. • More EIRP and less complex coverage algorithms for Channel 1, 3 users.	• New algorithm S/W needed • Less coverage flexibility for Channel 1, 3 • Lose spot beam coverage mode for Channel 1, 3
S/C:	-	• Redo Weight/Thermal/ Structures Balance for additional antennas, waveguide, cabling, etc. • Hardware changes for additional (New) commands
SCCE:	• Simplified pointing algorithms for Channel 1, 3 • Reduced processor load from 2 MBX databases to one • Increased Beacon EIRP (helps overcome scintillation effects)	• Added configuration CMDS for GDA, steerable horns, and VPD • Additional TLM processing • New pattern S/W needed including pointing constraints for 2 GDA's on same frequency.

3.2.1.4 Transponder Linearization Options, Comm Subsystem Considerations

Two concepts have been studied for the linearization of transponder channels to obtain more useful power output. The first is the use of the 16 watt ultra linear SSA, and the second is the use of a linearizer device which pre-distorts signals to compensate for gain compression in the power amplifier.

The DSCS transponders each consist of two non-linear amplifiers, with both contributing to the generation of IM products. One of these amplifiers is the FETAL, and the second is the output power amplifier. Because of the non-linearity of the power amplifiers, the FETAL amplifiers which precede the power amplifiers are more "backed-off" than are the final power amplifiers. Thus in the present DSCS transponder alignment, the power amplifiers produce the higher IM levels at 3 to 6 dB back-off because the FETAL's will be 8 to 11 dB backed-off respectively. If, however, the output power amplifiers are made perfectly linear, then the FETAL's will be backed-off only 3 to 6 dB, instead of 8 to 11 dB producing potentially, more IM products at the output of the transponders than do the present non-linear power amplifiers.

In the case of the ultra-linear SSA, the greater linear power output is achieved not because the power amplifier is more linear, but because it is a higher power amplifier. Thus, if during alignment, the power amplifier is aligned to operate saturated at 5 dB gain compression or more, then at 3 dB back-off, the FETAL will be backed-off 3 + 5 = 8 dB or more, reducing the IM products contributed by the FETAL, and therefore not requiring any linearization of the FETAL.

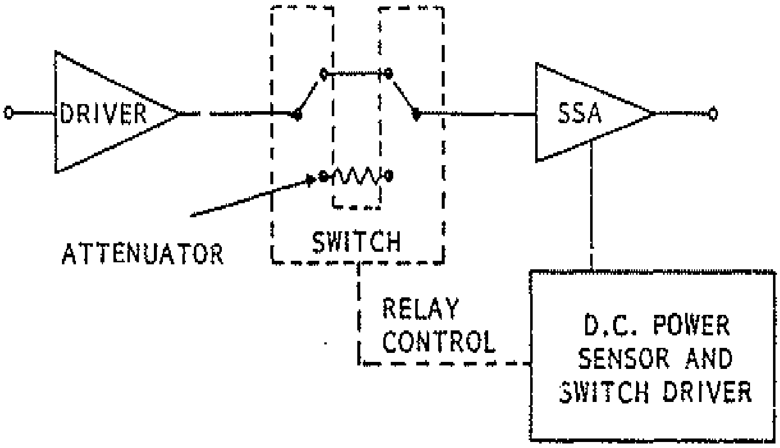
Operating a 16 watt SSA saturated at 5 dB compression, however, could cause excessive system power consumption. In order to prevent a jammer or an interfering freindly signal from saturating the SSA at a high power consumption level, a mode switch must be incorporated which detects this condition and reduces the drive level.

This dual mode operation is illustrated in Figure 3-4. The nominal position of the switch bypasses the attenuator. If the Level 1 Command is sent, the switch driver is disabled so that the attenuator stays out of the circuit. Thus Level 1 operation implies saturation at a 16 watt level at high power consumption, which may be desireable during early mission life.

Level 2 operation enables the switch driver. In the linear mode the attenuator is bypassed, so linear operation is the same as linear operation in Level 1, with a low contribution of IM products from the FETAL. However, if a strong signal is detected for a predetermined duration, the switch is thrown and the drive level to the SSA is reduced dropping the saturated power output to a nominal 10 watts.

The linearizer device linearizes the transponder, as mentioned earlier, by pre-distorting the signal to compensate for the gain compression in the output power amplifier. Now that the power amplifier is linearized, the FETAL will be backed-off only 3 dB instead of 8 dB when the transponder (SSA) is backed-off 3 dB. Thus the IM products of the FETAL predominates even though the SSA has been linearized. This now requires that the FETAL be linearized.

To provide linearizing devices for the FETAL would be difficult and not practical because of the FETAL complexity and the 5 gain states that are selectable. Besides, a more effective means of linearizing any device is to back it off and drive it at lower power levels. Driving a linear device at lower input levels produces output levels that are proportionally lower. However, the FETAL contains an attenuator at its output which has an attenuation value of 15 dB or more. Each transponder has a 15 dB bypassable attenuator before each FETAL to set gain states greater than 5. Use can be made of these attenuators to reduce the drive level to the FETAL by 15 dB while maintaining the linear output level the same, thus reducing the IM products greater than 30 dB.



COMMAND	FUNCTION	LINEAR MODE	SAT. MODE
LEVEL 1	RESET LATCHING RELAY AND DISABLE SWITCH DRIVER	DC<48.7 W	DC~61 W
LEVEL 2	RESET LATCHING RELAY AND ENABLE SWITCH DRIVER	DC<48.7 W	DC<48.7 W

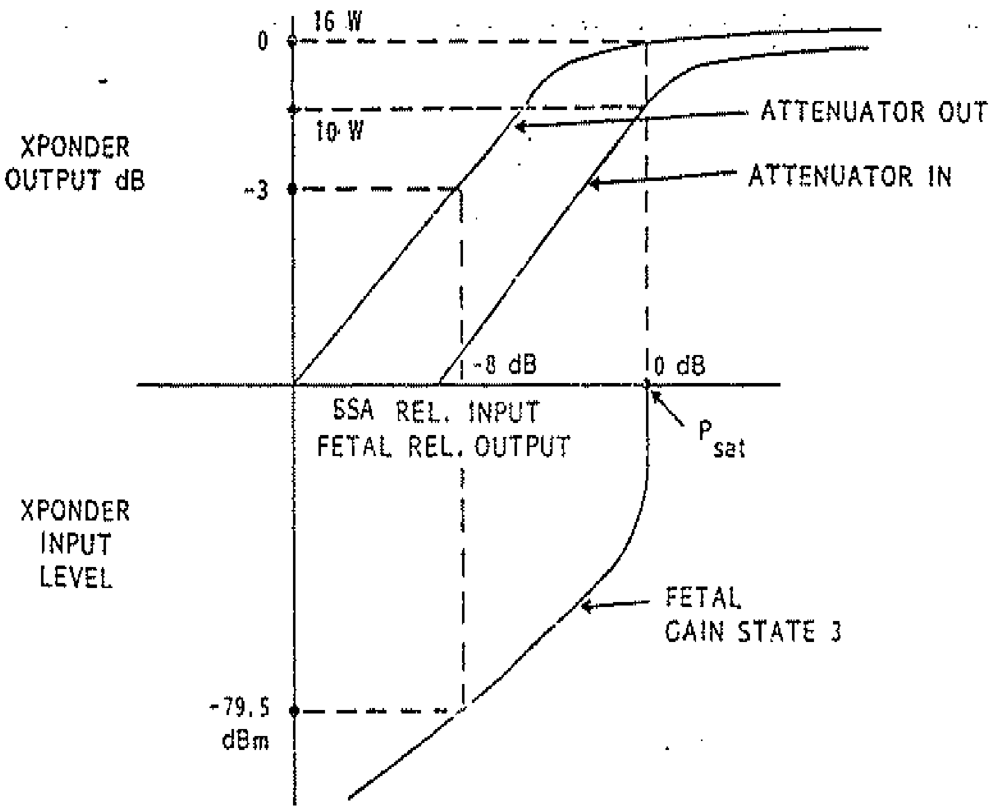


Figure 3-4. Dual Mode Ultra-linear SSA Operation

Figure 3-5 illustrates how this linearizing technique would operate. The nominal linear mode would place the input 15 dB pad in while taking the output 15 dB pad out.

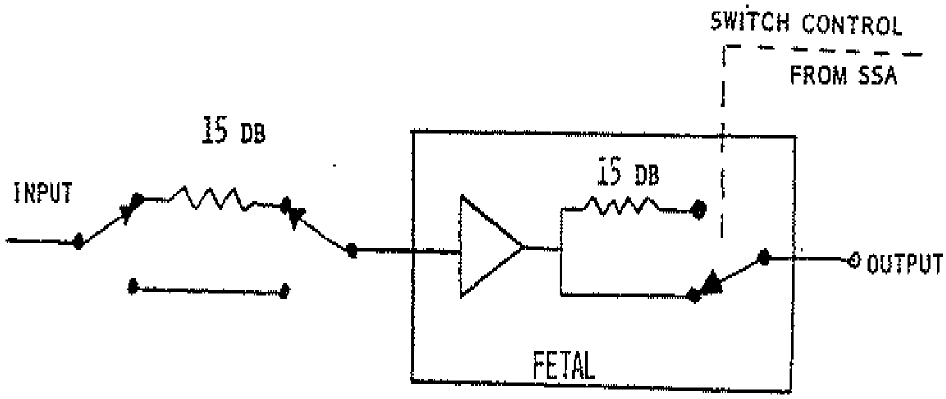
The presence of a jammer or strong interfering signal would cause the FETAL output to provide a saturated output level 15 dB higher than required for SSA saturation. This amount of overdrive would draw excessive DC power and possibly damage the SSA. Thus the same sensing circuit described for the ultra-linear SSA would be required to switch the output pad back into the circuit as shown in Figure 3-5. Since only 4 to 5 dB of additional back-off of the FETAL is necessary with the linearizer, 4 or 5 dB pads could be used instead of 15 dB, thereby reducing the risk of potential damage to the SSA. Reaction time of the sensing circuit to the strong signals must be fast to reduce the risk of SSA damage, and yet long enough to reduce the probability of a false alarm.

Option Package F considers the use of the ultra-linear SSA, while Option Package G considers the linearizing device. Combining the two options (F & G) would improve the performance in some channels even more. This is illustrated in Table 3-6 using present estimates of improvement factors.

Table 3-6. Linear Power Output Improvements, dB*

Channel	Option F	Option G	Option F G
1	NA	TBD	TBD
2	NA	TBD	TBD
3P, 4P, 5P, 6P	2.5	1	3.5
3R, 4R, 5R, 5R	NA	TBD	TBD

*Note: Estimated improvement is referenced to the present useful power output and IM level at 3 dB output back-off.



FETAL CONTROL TABLE

FETAL MODE	INPUT PAD	OUTPUT PAD
GAIN STATE 1	OUT	IN
GAIN STATE 2	OUT	IN
GAIN STATE 3	OUT	IN
GAIN STATE 4	OUT	IN
GAIN STATE 5	OUT	IN
GAIN STATE 6	IN	IN
GAIN STATE 7	IN	IN
GAIN STATE 8	IN	IN
GAIN STATE 9	IN	IN
GAIN STATE 10	IN	IN
LINEAR MODE GAIN STATE 1	IN	OUT
LINEAR MODE GAIN STATE 2	IN	OUT
LINEAR MODE GAIN STATE 3	IN	OUT
LINEAR MODE GAIN STATE 4	IN	OUT
LINEAR MODE GAIN STATE 5	IN	OUT

Figure 3-5. FETAL Linearizer

3.3 MECHANICAL SYSTEM LEVEL REQUIREMENTS COMPLIANCE

The configurations described in Section 2 were evaluated with regard to compliance with the following system level mechanical requirements:

- Mass Properties
- Envelope
- Sensor/Antenna Fields of View

Thermal Design and mechanical loads impacts were not evaluted. However, no major problems are expected in these areas.

Payload Mass Properties and weight were evaluated relative to the STS/145 requirements of ICD-B-81203. Orbital Mass Properties were compared to the Attitude Control related requirements of the Satellite Mechanical Requirements Specification SVS 9355 X30.

3.3.1 MECHANICAL REQUIREMENTS COMPLIANCE SUMMARY RESULTS BY CONFIGURATION

PIR 1240-DSCS-84152A (see Appendix) provides a Mass Properties assessment of the configurations of this study. Configurations A, B and D results are summarized below in all cases envelope requirements and antenna/sensor fields of view are maintained.

CONFIGURATION A - Additional GDA's (2) mounted to C, Body - Z Panel.

- Marginally meets payload weight requirement of ICD-B-81203 with little or no room for growth/uncertainty (5208 lbs. vs. 5250 lbs. max)
- Satellite X and Z center of gravity location and travel fall out of spec.
    - Causes slight fuel usage penalty
    - Requires minor change to ACS imbedded software
- Satellite dry weight of 1962 lbs. marginally meets 1988 lb. max requirement.
- Envelope is compatible with STS/IUS requirements
- All sensor/antenna fields of view are maintained.

CONFIGURATION B - Multimode EC Transmit Antennas Replace Existing Design.

- All payload and satellite mass properties are within specified limits.
    - Payload weight - 5181 lbs.
    - Sat. dry weight - 1949 lbs.
- Envelope is compatible with STS/IUS requirements.
- All sensor/antenna fields of view are maintained.

CONFIGURATION D - Configurations A plus B with a 4 feed Kidney beam reflector antenna replacing mix.

- Payload weight and satellite dry weight are within specified limits
    - Payload weight - 5116 lbs.
    - Sat. dry weignt - 1916 lbs.
- Satellite Z CG and CG travel falls out of spec.
    - Minor fuel impact
    - Minor ACS software impact
- Envelope is compatible with STS/IUS requirements
- All sensor and antenna fields of view are maintained.

3.4 ELECTRICAL SYSTEM IMPACT

3.4.1 COMMAND AND TELEMETRY

The following chart summarizes the impact the proposed enhancement options would have on the TT&C system. Of the enhancements proposed, the multimode earth coverage horn, the TLS improvements and the VCO improvements require no additional commands or telemetry monitors.

A total of 10 discrete commands, 2 message commands, 10 bit-level TLM monitors, and 2 serial monitors would need to be added to the telemetry matrix to support the remaining enhancement options. All of these requirements can be accommodated using the existing CTU and RTU components.

3.4.2 ACE DESIGN

The attitude control electronics (ACE) will need modification to account for an additional gimballed dish antenna (GDA) drive.

Circuit boards for the X' and Y' gimbals will need to be integrated into the existing design. This would require a backplane wiring change to bring the drive signals to the ACE connector. In addition, the existing ACE connector may need to be replaced with a larger connector.

A spare hard RAM command will be used to turn the new X' and Y' gimbal circuit boards on and off. In addition, the embedded PROM software would need modification to recognize the new X' and Y' message commands and to access the GDA circuit boards.

SPACE SYSTEMS DIVISION

COMMAND AND TELEMETRY IMPACT

OPTION/TASK	ADDITIONAL REQUIREMENTS: COMMANDS		ADDITIONAL REQUIREMENTS: TLM MONITOR	
	DISCRETE	MESSAGE	BI-LEVEL	SERIAL
• ADDITIONAL GIMBALLED DISH ANTENNA	6	1	5	2
• MULTI-MODE EARTH COVERAGE HORN	-	-	-	-
• STEERABLE HEMISPHERE COVERAGE HORN (KIDNEY BEAM)	-	1	3	-
• ULTRA-LINEAR SSA (EACH)	2	0	1	-
• LINEARIZING DEVICE (EACH)	2	0	1	-
• TLS IMPROVEMENT	-	-	-	-
• VCO IMPROVEMENTS	-	-	-	-

ABOVE ADDITIONAL REQUIREMENTS CAN BE ACCOMMODATED IN THE EXISTING CTU AND RTU COMPONENTS

3.4.3 POWER SUBSYSTEM

The maximum average power impact the enhancements will cause is a 22.6 watt increase in power required. The increase is caused by:

- Second GDA - +6 watts average power for heaters
- Ultralinear SSA - +11 watts for saturated opeation
  - +0 watts for linear operation
- Linearizers - +5.6 watts average power
  (0.94 w/CH * 6 channels)

The increased power consumption of the ULSSA in the saturated mode is payload-operator controlled. If the spacecraft is power-limited at the end-of-mission, the ULSSA can be switched into a mode that will limit power delta to zero.

The ACE redesign effective for the B9 spacecraft saves 10 watts, but the above mentioned changes would undo this 10 watt savings and the power budget would then be the same as the B8 spacecraft case. (See Tables 3-7 and 3-8.)

Table 3-7. Load Deltas Between Spacecrafts (IIIA) as Baseline)

Subsystem/Component	Δ (W)	A3	B4	B5	B6	B7	B8	B9
• BATSON II	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
• EP&D	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
• SCT SHF Downlink	39	-	39	39	39	39	39	39
• SSA (10W)	11.5 (ea)	-	11.5	-	34.5	46	46	46
• Generic TWTA (40W)	5.0 (ea)	-	-	-	-	-	10	10
• ACE Design								(10)
Load Increase over A1/A2 S/C Totals		9.5	60	48.5	83	94.5	104.5	94.5

Table 3-8. Power Shortfall B4 through B9

		Mission Years from Launch						
		10		9		8		7
Spacecraft	Mode	Autumnal Equinox	Spring Equinox	Autumnal Equinox	Spring Equinox	Autumnal Equinox	Spring Equinox	Autumnal Equinox
B4	Natural + Artificial	6.7						
	Natural							
	Artificial							
	One String Failed	32.7	16.8	17.8	1.1	2.2		
B5	Natural							
	Artificial							
	One String Failed	24.6	8.8	9.7				
B6	Natural + Artificial	8.2						
	Natural							
	Artificial							
	One String Failed	34.9	15.6	19.7	-	3.7		
B7	Natural + Artificial	18.8	-	2.5				
	Natural							
	Artificial							
	One String Failed	44.6	26.0	30.1	10.0	14.4		
B8	Natural + Artificial	20.4	5.4	9.0				
	Natural							
	Artificial							
	One String Failed	46.3	33.1	36.3	22.0	25.5	10.5	14.4
B9	Natural + Artificial	18.8	-	2.5				
	Natural							
	Artificial							
	One String Failed	44.6	26.0	30.1	10.0	14.4		

SECTION 4

OPTION PACKAGES - SELECTION

SECTION 4

OPTION PACKAGES - SELECTION

4.1 OPTIONS PACKAGE, SUMMARY/RECOMMENDATIONS

Table 4-1 lists 10 option packages including 7 concepts originally defined for this study program, and 3 additional combinations. Each option package is characterized by its contribution to satellite weight, power, risk, schedule, performance, operational constraints, and impacts to the DSCS system, as well as costs, through 814.

For the purpose of comparison, it is assumed that the schedule risks, operational constraints, and system impacts are of approximately equal or negligible consequence for each option compared to weight, power and performance. The figure of merit numbers in Table 4-2 for weight and power are assigned by ranking where the smallest number is the highest rank (lowest weight or power consumption). The ranking of performance is more subjective. However, an attempt is made to put a priority on increased EIRP, where in Table 4-2 the greatest performance has the lowest FOM. The total listed in Table 4-2 is the sum of the weight, power and performance FOM's.

Table 4-3 sorts the configurations from highest rank (lowest FOM = most desireable) to lowest rank. Where configurations are tied with equal FOM's the cost basis is used to break the ties.

GE recommends that a selection be made from one of the top three ranked configurations, K, F and J. GE believes that performance should be the prime consideration. It should be noted that the three top ranked configurations were also ranked in the top three for performance, where weight and power were not considerations. The final decision must be made by factoring in rating factors for available funds, user needs, and weight and power.

Table 4-1. Summary of Option Configuration/Characteristics

OPTION PACKAGE	Δ WEIGHT (LBS)	Δ POWER (WATTS)	SCHEDULE RISKS	SCHEDULE (S/C)	PERFORMANCE IMPROVEMENT	OPERATIONAL CONSTRAINTS	SAT. & SCCE USER IMPACTS	RATIO ROM
A. ADDITIONAL GDA NEW C15-2T FL 8-2 MISC TOTAL Δ WT.	23 3.7 1 3 30.7	TBD	MODERATE	814	(1) CHAN 2 EIRP TYPICALLY 44 dBW FROM EITHER GDA, OR 41 dBW SIMULTANEOUSLY FROM BOTH GDA'S—OR ANY MIX. (2) NO CONSTRAINTS FOR CHAN 2 COVERAGE DUE TO CH 1 AND CH 4 USERS. CH 2 IS SOLE USER OF 2ND GDA	MINIMUM BEAM SEPARATION-REQUIRED FOR CHANNEL 2 DUAL BEAM COVERAGE	• DECODER/ENCODER • COMMANDS FOR 2ND GDA • COMMANDS FOR VPD • ADDITIONAL TLM • ADDITIONAL HEATER PWR.	5.9
B. IMPROVED ECH HORNS (12")	8	0	LOW	814	(1) LESS VARIATION IN SIGNAL LEVEL OVER SURFACE OF EARTH (2) GREATER SIGNAL LEVELS OVER 59% OF EARTH AT EDGE OF EARTH	RE-CALCULATE BEACON SPECTRAL DENSITY AT EDGE OF EARTH	NEW ALLOCATION S/W NEEDED (ANT. COVERAGE)	1.13
D. REMOVE MIX REPLACE WITH STEERABLE KIDNEY BEAM ADD 2ND GDA USE IMPROVED ECH HORNS TOTAL Δ WT	-64.5 10.3 30.7 8.0 -15.5	TBD	MODERATE	814	(1) SAME AS FOR A & B ABOVE (2) AVERAGE EIRP INCREASE OF 1.5 dB OF KIDNEY BEAM OVER MIX WITH SIMILAR COVERAGE	(1) SAME AS FOR A & B ABOVE (2) NARROW COVERAGE BEAM NOT AVAILABLE WITH STEERABLE KIDNEY BEAM (3) LESS COVERAGE FLEXIBILITY	(1) SAME AS A & B ABOVE, EXCEPT REDUCED COMPLEXITY AND NUMBER OF COMMANDS FOR ANT. CONTROL (2) NEW PATTERN ALGORITHM (3) LESS S/C WEIGHT	11.9
F. ULTRA-LINEAR SSA	0	0 FOR LINEAR OPERATION	LOW	814	(1) 2.5 dB MORE EIRP IN 10 WATT CHANNELS (3,4,5 & 6) (SATURATED & LINEAR)	(1) JAMMER OR HIGH USER SIGNAL LEVEL CAN DISABLE LINEAR OPERATION	(1) REQUIRED ADDITIONAL COMMANDS (2) MORE PRIME POWER NEEDED FOR 16 WATT SATURATED OPERATION	8.2
G. USE OF LINEARIZING DEVICE	4	9.4	LOW	814	(1) APPROX. 1 dB INCREASE IN LINEAR EIRP WITH SSA'S, APPROX. 7 dB FOR TWTA'S	NONE	REQUIRES MODIFICATION TO FETAL FOR IMPROVED IM PERFORMANCE	3.4

Table 4-1. Summary of Option Configuration/Characteristics (Cont.)

OPTION PACKAGE	Δ WEIGHT (LBS)	Δ POWER (WATTS)	SCHEDULE RISKS	SCHEDULE S/C	PERFORMANCE IMPROVEMENT	OPERATIONAL CONSTRAINTS	SAT. & SCCE USER IMPACTS	RATIO ROM
F. + G. LINEARIZE AND ULTRA LINEAR SSA	4	9.4	LOW	B14	(1) APPROX. 3.5 dB MOVE LINEAR EIRP FOR SSA CHANNELS (2) SAME AS G FOR TWTA CHANNELS	(1) SAME AS F ABOVE	SAME AS F & G ABOVE	11.6
H. TLS ACCURACY IMPROVEMENTS	0	0	LOW	B14	REMOVES AMBIGUITY AT OR NEAR SATURATION. ALLOWS ACCURATE DETERMINATION OF POWER OUTPUT UP TO SATURATION INSTEAD OF UP TO 2 dB BELOW SATURATION	NONE	NONE	1
I. IMPROVED VCO'S	0	0	LOW	B14	(1) MORE STABLE OSCILLATOR RESULTING IN LESS DEGRADATION TO AM/PM TESTS. (2) LOWER WIDEBAND PHASE NOISE	NONE	NONE	1.3
J. = ALL OF THE ABOVE	-11.5	9.4 +TBD	MODERATE	B14	(1) 1.5 dB MORE CHAN 1 EIRP THROUGH KIDNEY BEAM (2) 1.5 dB MORE CHAN 3 TWTA EIRP THROUGH KIDNEY BEAM (3) 1.5 dB MORE CHAN 3 SSA SATURATED EIRP THROUGH KIDNEY BEAM (4) 5.0 dB MORE LINEAR CHAN 3 SSA EIRP THROUGH KIDNEY BEAM (5) SAME AS D, F, G, H, AND I, ABOVE	SAME AS D, F, G, H AND I ABOVE	SAME AS D, F, G, H AND I ABOVE	25.8
K. = J-G	-15.5	TBD	MODERATE	B14	SAME AS J. ABOVE EXCEPT ONLY 4 dB MORE CHAN 3 LINEAR EIRP THROUGH KIDNEY BEAM.	SAME AS J.	SAME AS J.	22.3

Table 4-2. Figure of Merit Analysis

Configuraton	FOM Wt.	FOM Pwr.	FOM Performance	FOM Total
A	6	2	6	14
B	5	1	8	14
D	1	2	5	8
F	3	1	3	7
G	4	3	7	14
F&G	4	3	4	11
H	3	1	9	13
I	3	1	10	14
J -	2	4	1	7
K	1	2	2	5

Table 4-3. Total FOM Ranking

Total FOM	Configuration	Rel. Cost*	Rank
5	K	22.3	1
7	F	8.2	2
7	J	25.8	3
8	D	11.8	4
11	F&G	11.6	5
13	H	1	6
14	B	1.1	7
14	I	1.3	8
14	G	3.4	9
14	A	5.9	10

* Relative Cost (Development and 814 Production) used to separate ties.

APPENDIX A

STATEMENT OF WORK AND WEIGHT SUMMARY PIR

*Note: This page considered to be in italics

SPECIAL STUDY TASK II

SHF Communications Enhancement

Objective: Assess alternate methods for improving the SHF communications capabilities on satellites III-B8 to III-B14.

Estimated Cost: 1500 hours.

Period of Performance: 15 Jan 86 to 15 May 86.

The Contractor Shall:

1.0 Special Study Tasks.

1.1 Perform the analyses necessary to determine the benefits and penalties for implementing the following improvement concepts with respect to: (1) SHF communications service, (2) spacecraft systems, and (3) SCCE systems. Also, perform the analyses necessary to determine the effort required to develop and implement these concepts.

a. Additional Gimballed Dish Antenna (GDA).

b. Multi-mode Earth Coverage Horn (ECH).

c. Steerable hemisphere coverage horn.

d. Removal of one transmit multi-beam antenna (MBX) in combination with concepts a, b and c.

e. Variable RF power splitter between the GDA and MBX in channel two.

f. Ultra-linear solid state amplifier for ten watt channels.

g. Linearizing device for all channels.

h. Transmit level sensor (TLS) accuracy improvement.

i. Improved 200 Mhz and 725 Mhz voltage controlled oscillators.

1.2 Develop upgrade options using combinations of the above concepts that could be implemented without impacting spacecraft weight and power. Perform analyses to determine the improvement to SHF service for each option package developed.

1.3 Provide the following information for each improvement concept and option package.

a. Technical description including weight, power, and the expected performance improvement.

b. Satellite and SCCE systems impacts detailing any hardware or software modifications.

Note: This page considered to be in italics

c. Operational constraints and considerations.

d. Development and implementation risks.

e. Proposed development and implementation schedules and identification of vehicles which could be impacted.

f. Rough Order of Magnitude (ROM) cost estimate for development, production, and parts by GFY.

g. Figure of merit combining the above factors for comparison and your recommendation as to the desireability for implementation.

2.0 Administrative Tasks.

2.1 Provide the following meetings and documentation.

a. Kick-off meeting not later than 2 weeks after the start of this study.

b. Final presentation not later than 1 month after the end of this study.

c. Status reports at the monthly technical/management meetings (CDRL 004A6).

d. Final report. The report should be in sufficient detail for using agencies to evaluate the application of each improvement concept and option package to their requirements (CDRL 043A6).

GENERAL ELECTRIC
SPACE DIVISION
PHILADELPHIA
PROGRAM INFORMATION REQUEST/RELEASE

*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
U	1240	DSCS	B-4152	*A

PIR NO. — — —

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FM P. DeMartino, Mechanical Systems Engineer
J. Stanton, Mass Properties Analysis

TO Distribution

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE D.A. NO.
4/17/86			

SUBJECT

ASSESSMENT OF SHF ENHANCEMENT CONFIGURATIONS

INFORMATION REQUESTED/RELEASED

Summary of Mass Properties Evaluation

- Configuration A (Two GDA's mounted to -Z center body panel)
  - The payload weight is marginal with respect to the ICD limit for an IUS/STS launch (little or no room for growth/uncertainty).
  - The X and Z CG and CG travel are out of spec but should be acceptable with some modifications to the ACS imbedded software. A small propellant weight penalty will be incurred as well.
  - Satellite dry weight is marginal with respect to the current limit. This should not be of concern provided that ACS and launch vehicle performance requirements can be met.
- Configuration B (Two new Multimode" Earth coverage Transmit horns)
  - The new antenna (see attached sketch) is 6.6 pounds versus 2 pounds for the existing units.
  - All mass properties are within their specified limits.
- Configuration C (Two GDA's per Configuration A plus Multimode E. C. antennas per Configuration B plus Kidney Beam Reflector with 4 feeds)
  - Payload weight will be out of limits for IUS/STS launch
  - The X and Z CG's and CG travel are out of spec., but somewhat less so than Configuration A.
  - The satellite dry weight will be marginally out of spec for this configuration.
- Configuration D (Same as Configuration C except the North 19 MBA is removed).
  - Payload weight is within ICD requirements for an IUS/STS launch.

*Rev. A - New Configuration D in Attachment.

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PAGE NO. 1 OF 3 plus attach.

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- The Z CG and travel are out of specified limits. However, the comments associated with this condition for Configuration A still apply.

- The Satellite Dry weight will be within its specified limit.

Discussion

- Configuration A

The mass properties analysis results for configuration A are as shown in the attachment. The launch module weight indicated is compared to the requirement of Figure 1. The payload weight shown is typical based on a currently planned 810 spacecraft and is not worst case with regard to RF amplifier compliment. The dry weights included (summarized in front of each configuration attachment) will give expected values for all other mass properties values. Weights not accounted for at this time but considered a "wash" are North Panel (Transponder) and Satellite housekeeping Subsystem changes.

A maximum payload weight for Configuration A is:

5208	lbs.	(Per the aforementioned data)
26	lbs.	(measurement accuracy)
28	lbs.	(assuming 6 WJ 40W's)
4	lbs.	(assuming 4 WH 40W TWTAS)
5266	lb.	(greater than ICD amount of 5250 lbs.)

It is probably not likely that the heaviest RF amplifier compliment would be used, however, even neglecting the 32 lb. delta weight associated with this situation gives us a payload weight of 5234 lbs. which is considered marginal since the analysis is preliminary at this time.

As can also be seen in the attached data, the spacecraft X and Z CG and CG travel limits are exceeded. This will increase disturbance torques and as such will have an effect on command thruster pulse widths and attitude error. There would also be a minor impact to fuel usage. However, our ACS people have indicated that CG offsets of this magnitude can be tolerated by our system with changes in imbedded software.

The satellite dry weight limit (1988 lbs. per SVS 8950-Prime Item Specification) is also marginal for this configuration if, in particular, we add 16 lbs. for a heavy RF amplifier compliment.

• Configuration B

The mass properties analysis results, as attached, show compliance to all requirements. The weight increase is about 8 lbs. per spacecraft over the current sattelite. (The weight for the new "multi-mode" Earth Coverage antenna is 6.3 lbs. versus approximately 2 lbs. for the existing E. C. transmit horn).

The station location at the top of the antenna must be kept at station 77.5 (1.25 inches from the mating interface) to meet IUS envelope limits. This will require some minor modifications to the centerbody structure which must be trimmed for clearance local to the antennas.

• Configuration C

The mass properties analyses results for Configuration C are as shown in the attachment. The launch module weight indicated when increased for measurement accuracy and maximum RF amplifier compliment will exceed the Figure 1 limits.

The X and Z CG and CG travel requirements are also exceeded but somewhat less so than Configuration A. As this is the case the comments made for the A configuration apply with respect to attitude control performance.

• Configuration D

The mass properties analysis resuls for Configuration D, as shown in the attachment, are within Figure 1 ICD limits.

The Z CG and travel are out of the currently defined limits and as such will impact ACS imbedded sofware as previously stated.

Table 3.2-2. DSCS III/III Mass Property Limits

		Mass	Center of Mass (CM) (in)			Centroidal Moments of Inertia (slug-feet2)			Centridal Products Of Inertia (slug-feet2)		
		(lb)	X_S	Y_S	Z_S	I_{XX}	I_{YY}	I_{ZZ}	I_{XY}	I_{XZ}	I_{YZ}
FWD DSCS III SATELLITE (SEPARATED)	-MIN	2497	-2.3	0.0	+30.2	530	410	620	-30	-30	-20
	-MAX	2592	0.0	+2.5	+32.1	670	520	790	+30	+30	+20
AFT DSCS III SATELLITE (SEPARATED)	-MIN	2513	0.0	0.0	-32.1	530	410	620	-30	-30	-20
	-MAX	2608	+2.3	+2.5	-30.2	670	520	790	+30	+30	+20
PAYLOAD BOOSTER ADAPTER (REMAINS WITH IUS)	-MIN	40	-0.5	+2.2	-67.1	11	14	23	-1	-1	-1
	-MAX	50	+0.5	+3.2	-65.1	17	22	36	+1	+1	+1
LAUNCH (TOTAL)	-MIN	5050	-1.2	0.0	-1.7	2100	1850	1300	-75	-200	-150
	-MAX	5250	+ 1.2	+ 2.6	+ 0.4	2750	2450	1650	+ 75	+ 200	+ 150

NOTES: (1) Referenced to X_S, Y_S, Z_S, and min/max CM as defined in figure 3.1-1.

(2) All mass properties include measurement accuracies of paragraph 3.2.2.2.2.

FIGURE 1 - CURRENT ICD M.P. LIMITS

4-15-96

CONFIG. r

DRY WT./SC	1962.2	INCLUDES:
(4) 40W TWTA HEDD	56.8	
(4) 10W HESSA	31.2	
(2) 10W TWTA HEDD	14.6	
(2) GDA	49.2	
(4) TANTALUM SHLDS	6.3	
NEW SOLAR ARRAY WO/"CIC" CELLS	129.7	
NEW CB STRUCT	177.5	
NEW ACE	50.8	

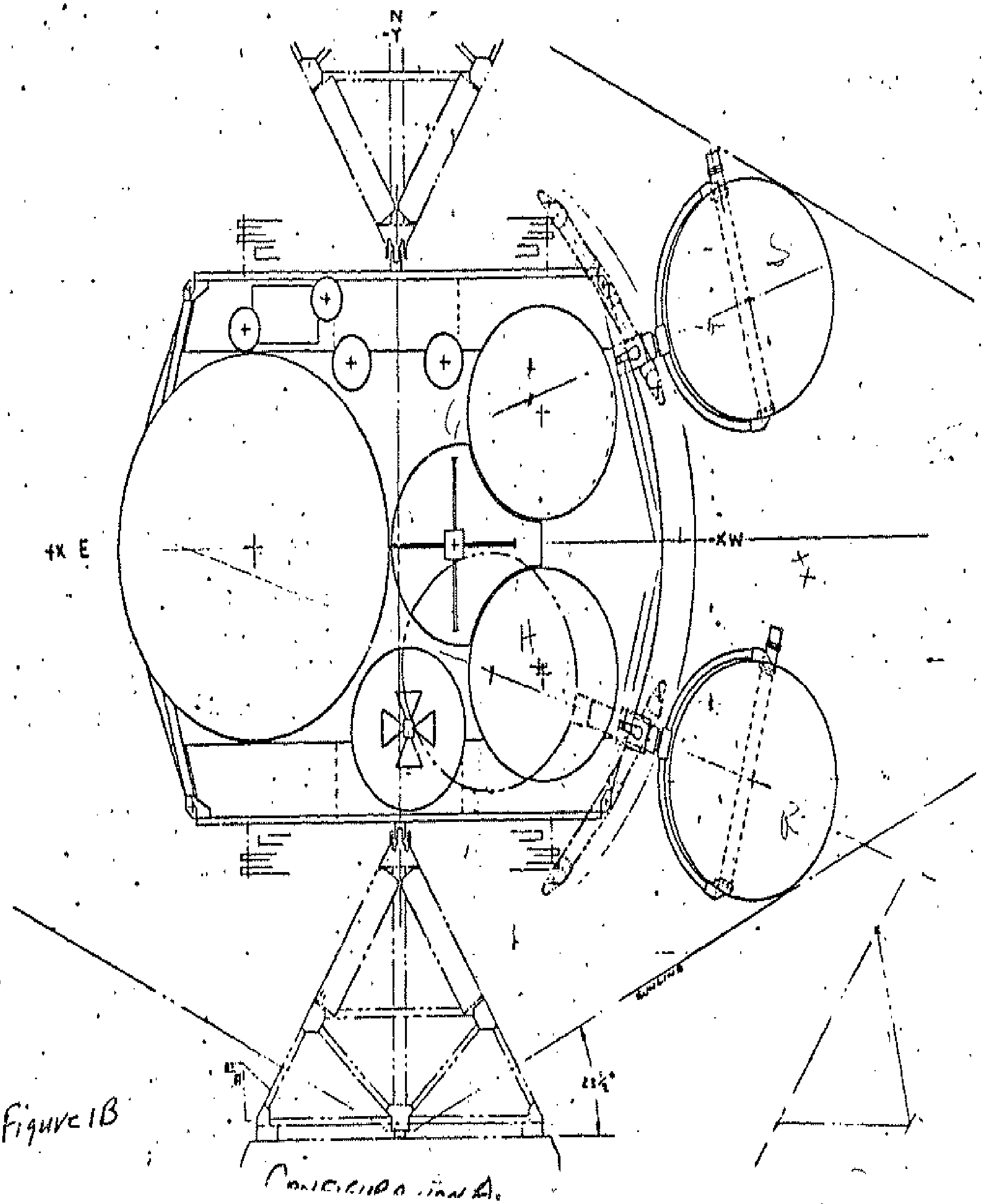


Figure 1B

Configuration A.

CONFIG. A

4.0 SEQUENTIAL MASS PROPERTIES DATA

4.1 PAYLOAD LAUNCH TO PAYLOAD SEPARATION

ITEM MISSION EVENT	WEIGHT (LBS.)	CENTER OF MASS INCHES			MOMENTS OF INERTIA SLUG FT2			PRODUCTS OF INERTIA SLUG FT2		
	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
PAYLOAD LAUNCH MODULE DSCS III/II	5207.8	-0.0	-0.6	1.2	2277.	1425.	2017.	-35.9	-0.8	-2.2
UPSC IB DSCS III SEPARATED	2576.7	-1.4	30.6	1.1	586.	694.	453.	5.3	-11.8	-5.4
LWSC IB DSCS III + ADAPTER	2631.1	1.3	-31.2	1.2	617.	729.	487.	5.1	11.0	4.1
LWSC IB DSCS III SEPARATED	2586.1	1.3	-30.6	1.2	591.	699.	458.	4.6	11.0	4.7
ADAPTER DSCS III	45.1	-0.0	-66.1	3.0	14.	30.	18.	0.0	-0.0	0.1

4.2 SEQUENTIAL MASS PROPERTIES DATA - PAYLOAD BOM THROUGH PAYLOAD EOM

4.2.1 UPPER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
UPSC IB GE REF GA S SEP SA STOWED	2576.7	-1.4	30.6	1.1	586.	694.	453.	5.3	-11.8	-5.4
UPSC IB GE REF GA S SEP SA DEPLOYED	2576.7	-1.4	30.2	1.1	1079.	1203.	437.	5.0	-12.4	-5.0
UPSC IB GE REF BOL GA&SA DEP	2576.7	-1.9	30.2	1.1	1085.	1231.	462.	13.9	-10.8	-4.9
UPSC IB GE REF EOL GA&SA DEP	1974.7	-2.3	29.4	1.5	1031.	1199.	434.	13.3	-10.5	-4.4

4.2.2 LOWER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
LWSC IB DSCS III SEPARATED	2586.1	-1.3	30.6	1.2	591.	699.	458.	4.6	-11.0	-4.7
LWSC IB GDA STOWED ARY DEPLOYED	2586.1	-1.3	30.2	1.2	1083.	1208.	441.	4.4	-11.6	-4.3
LWSC IB GDA DEPLOYE ARY DEPLOYED	2586.1	-1.8	30.2	1.2	1089.	1237.	466.	13.2	-10.0	-4.2
LWSC IB AT PROPELLA DEPLETION	1984.1	-2.2	29.4	1.5	1036.	1205.	438.	12.7	-9.8	-3.7

COORDINATE REFERENCE AXES ARE SHOWN IN SECTION 5.1

CONFIG. M

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.3 ORBITAL MASS PROPERTIES VARIATION - UPPER SATELLITE

4.3.1 ORBITAL MASS PROPERTIES VARIATION - BOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2576.7	-1.88	30.18	1.15	1085	1231	462	13.9	-10.8	-4.9
3 PM	2576.7	-1.90	30.19	1.15	1089	1227	462	9.4	-10.3	-3.8
6 PM	2576.7	-1.91	30.21	1.15	1094	1223	462	13.8	-9.2	-3.4
9 PM	2576.7	-1.90	30.23	1.15	1089	1227	462	18.3	-8.2	-3.9
12 M	2576.7	-1.88	30.23	1.15	1085	1231	462	13.9	-7.7	-5.0
3 AM	2576.7	-1.86	30.22	1.15	1089	1227	462	9.5	-8.2	-6.0
6 AM	2576.7	-1.85	30.20	1.15	1094	1223	462	14.0	-9.3	-6.5
9 AM	2576.7	-1.86	30.18	1.15	1089	1227	462	18.4	-10.4	-6.0

4.3.2 ORBITAL MASS PROPERTIES VARIATION - EOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	1974.7	-2.28	29.39	1.50	1031	1199	434	13.3	-10.5	-4.4
3 PM	1974.7	-2.31	29.40	1.50	1036	1195	434	8.8	-10.1	-3.4
6 PM	1974.7	-2.32	29.43	1.50	1041	1190	434	13.3	-9.0	-2.9
9 PM	1974.7	-2.30	29.45	1.50	1036	1195	434	17.7	-7.9	-3.4
12 M	1974.7	-2.28	29.46	1.50	1032	1199	434	13.4	-7.5	-4.5
3 AM	1974.7	-2.25	29.45	1.50	1036	1195	434	9.0	-7.9	-5.6
6 AM	1974.7	-2.24	29.43	1.50	1040	1191	434	13.4	-9.0	-6.0
9 AM	1974.7	-2.25	29.40	1.50	1036	1195	434	17.8	-10.1	-5.5

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

Config A

1.3 CRITICAL MASS PROPERTIES

1.3.1 UPPER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.91	-0.11
Y OFFSET FROM Z AXIS(IN.)	+2.0 TO 0.0	1.15	0.85
Z STATION	STA 30.7 TO STA 31.6	30.18	-0.52
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	+0.2 TO -2.2	-2.32	-0.12
Y OFFSET FROM Z AXIS(IN.)	-2.6 TO 0.0	1.50	1.10
Z STATION	STA 30.2 TO STA 31.3	29.39	-0.81
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.47	-0.07
Y TRAVEL(IN.)	0.6	0.35	0.25
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	0.82	-0.22
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	1.61	-0.81
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	+25.0	17.8	7.2
POXY(SLUG-FT2)	+25.0	-10.8	14.2
POZY(SLUG-FT2)	+15.0	-6.5	8.5
IXX (SLUG-FT2)	1150 (MAX)	1094.	56.
	800 (MIN)	1031.	231.
IYY (SLUG-FT2)	500 (MAX)	462.	38.
	300 (MIN)	434.	134.
IZZ (SLUG-FT2)	1300 (MAX)	1231.	69.
	900 (MIN)	1190.	290.

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG A

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.4 ORBITAL MASS PROPERTIES VARIATION - LOWER SATELLITE

4.4.1 ORBITAL MASS PROPERTIES VARIATION - BOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2586.1	-1.84	30.17	1.17	1089	1237	466	13.2	-10.0	-4.2
3 PM	2586.1	-1.85	30.18	1.17	1093	1232	466	8.8	-9.6	-3.1
6 PM	2586.1	-1.86	30.20	1.17	1098	1228	466	13.2	-8.5	-2.7
9 PM	2586.1	-1.85	30.22	1.17	1094	1232	466	17.7	-7.4	-3.2
12 M	2586.1	-1.83	30.22	1.17	1089	1237	466	13.3	-7.0	-4.3
3 AM	2586.1	-1.81	30.21	1.17	1094	1232	466	8.9	-7.4	-5.3
6 AM	2586.1	-1.81	30.19	1.17	1098	1228	466	13.3	-8.5	-5.8
9 AM	2586.1	-1.82	30.18	1.17	1093	1232	466	17.7	-9.6	-5.3

4.4.2 ORBITAL MASS PROPERTIES VARIATION - EOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	1984.1	-2.22	29.38	1.53	1036	1205	438	12.7	-9.8	-3.7
3 PM	1984.1	-2.25	29.40	1.53	1040	1200	438	8.2	-9.3	-2.6
6 PM	1984.1	-2.26	29.42	1.53	1045	1196	439	12.6	-8.2	-2.2
9 PM	1984.1	-2.24	29.45	1.53	1040	1200	439	17.1	-7.1	-2.7
12 M	1984.1	-2.22	29.46	1.53	1036	1205	439	12.8	-6.7	-3.8
3 AM	1984.1	-2.19	29.44	1.53	1040	1200	439	8.4	-7.2	-4.8
6 AM	1984.1	-2.18	29.42	1.53	1045	1196	439	12.8	-8.3	-5.3
9 AM	1984.1	-2.20	29.39	1.53	1040	1200	439	17.2	-9.3	-4.8

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG A

1.3 CRITICAL MASS PROPERTIES

1.3.2 LOWER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.86	-0.06
Y OFFSET FROM Z AXIS(IN.)	+2.0 TO 0.0	1.17	0.83
Z STATION	STA 30.7 TO STA 31.6	30.17	-0.53
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	+0.2 TO -2.2	-2.26	-0.06
Y OFFSET FROM Z AXIS(IN.)	+2.6 TO 0.0	1.53	1.07
Z STATION	STA 30.2 TO STA 31.3	29.38	-0.82
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.45	-0.05
Y TRAVEL(IN.)	0.6	0.36	0.24
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	0.83	-0.23
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	1.62	-0.82
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	+25.0	17.2	7.8
POXY(SLUG-FT2)	+25.0	-10.0	15.0
POZY(SLUG-FT2)	+15.0	-5.8	9.2
IXX (SLUG-FT2)	1150 (MAX)	1098.	52.
	800 (MIN)	1036.	236.
IYY (SLUG-FT2)	500 (MAX)	466.	34.
	300 (MIN)	438.	138.
IZZ (SLUG-FT2)	1300 (MAX)	1237.	63.
	900 (MIN)	1196.	296.

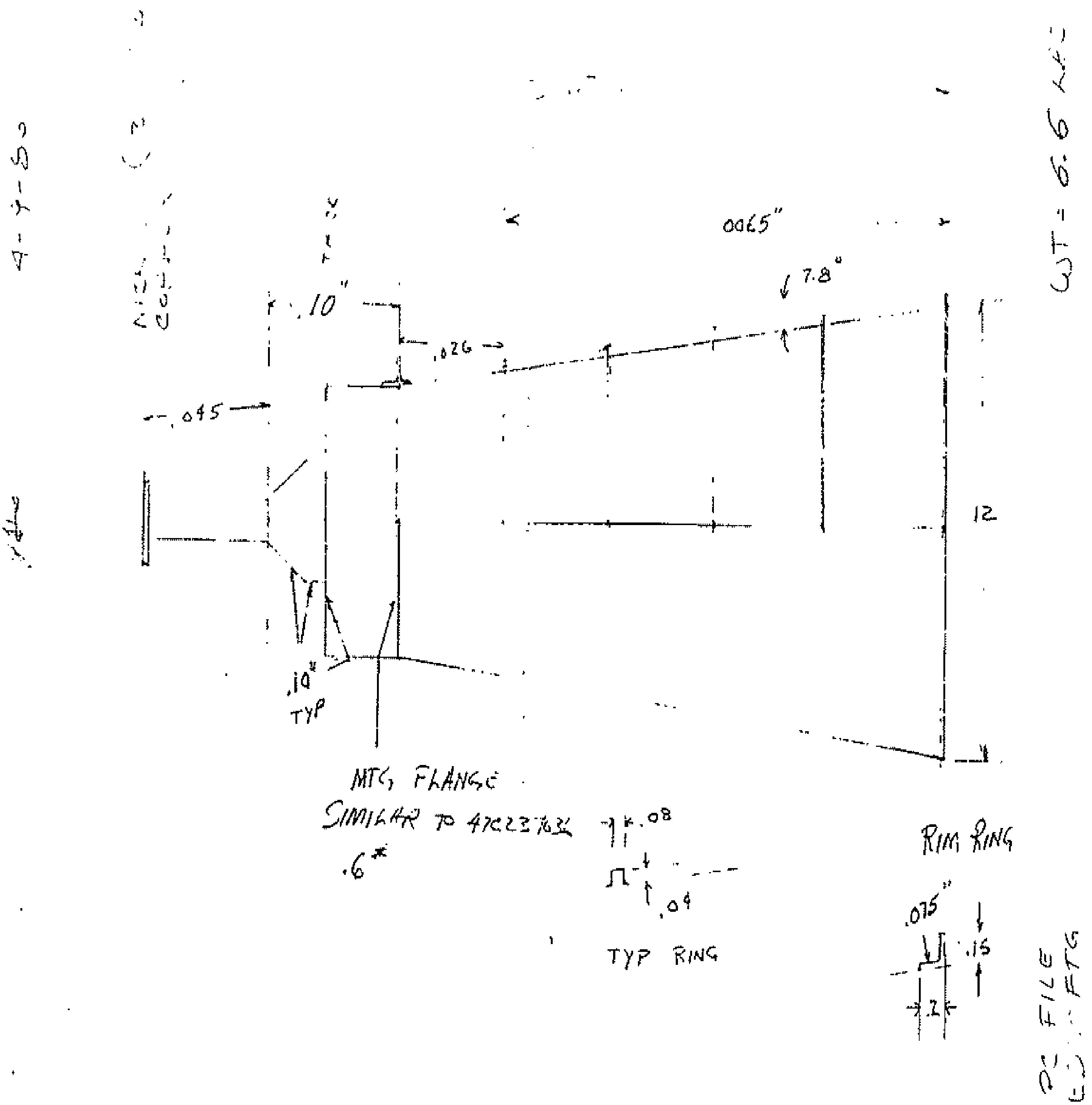
MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

4-15-96

CONFIG B

DRY WT 1949.1 INCLUDES:

(4)	40 W TWTA HEDD	56.8
(4)	10 W HESSA	31.2
(2)	10 W TWTA	14.6
(4)	TANTALUM SHLD	6.3
	NEW SOLAR ARRY / W/O "CIC" CELLS	129.7
	NEW CB STRUCT	177.5
	NEW ACE	50.9
(6)	MULTI MODE EC ANT	14.0



0065"
7.8°
.10"
.026
.045
12
.10"
TYP
MTG FLANGE
SIMILAR TO 47C237632
.6*
.08
.04
TYP RING
RIM RING
.075"
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MULTIMODE
A-15
WT = 6.6

Config. B.

4.0 SEQUENTIAL MASS PROPERTIES DATA

4.1 PAYLOAD LAUNCH TO PAYLOAD SEPARATION

ITEM MISSION EVENT	WEIGHT (LBS.)	CENTER OF MASS INCHES			MOMENTS OF INERTIA SLUG FT2			PRODUCTS OF INER SLUG FT2		
	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
PAYLOAD LAUNCH MODULE DSCS III/II	5181.4	-0.0	-0.6	1.1	2318.	1422.	2070.	-59.6	-0.8	-2.3
UPSC IB DSCS III SEPARATED	2563.5	-1.3	31.5	1.1	580.	692.	453.	-7.6	-12.1	-8.7
LWSC IB DSCS III + ADAPTER	2617.9	1.2	-32.1	1.2	610.	728.	487.	-7.8	11.3	7.5
LWSC IB DSCS III SEPARATED	2572.9	1.2	-31.5	1.1	584.	698.	458.	-8.2	11.4	8.0
ADAPTER DSCS III	45.1	-0.0	-66.1	3.0	14.	30.	18.	0.0	-0.0	0.1

4.2 SEQUENTIAL MASS PROPERTIES DATA - PAYLOAD BOM THROUGH PAYLOAD EOM

4.2.1 UPPER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
UPSC IB GE REF GA S SEP SA STOWED	2563.5	-1.3	31.5	1.1	580.	692.	453.	-7.6	-12.1	[illegible]
UPSC IB GE REF GA S SEP SA DEPLOYED	2563.5	-1.3	31.1	1.1	1073.	1201.	437.	-7.8	-12.8	-8.4
UPSC IB GE REF BOL GA&SA DEP	2563.5	-1.3	31.1	1.1	1073.	1203.	439.	-8.3	-13.3	-8.1
UPSC IB GE REF EOL GA&SA DEP	1961.5	-1.5	30.5	1.5	1020.	1171.	412.	-8.5	-13.1	-7.8

4.2.2 LOWER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
LWSC IB DSCS III SEPARATED	2572.9	-1.2	31.5	1.1	584.	698.	458.	-8.2	-11.4	-8.0
LWSC IB GDA STOWED ARY DEPLOYED	2572.9	-1.2	31.0	1.1	1077.	1207.	442.	-8.5	-12.0	-7.7
LWSC IB GDA DEPLOYE ARY DEPLOYED	2572.9	-1.3	31.0	1.1	1077.	1208.	443.	-8.9	-12.5	-7.4
LWSC IB AT PROPELLA DEPLETION	1970.9	-1.5	30.5	1.5	1025.	1176.	416.	-9.1	-12.4	-7.1

COORDINATE REFERENCE AXES ARE SHOWN IN SECTION 5.1

CONFIG D

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.3 ORBITAL MASS PROPERTIES VARIATION - UPPER SATELLITE

4.3.1 ORBITAL MASS PROPERTIES VARIATION - BOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2563.5	-1.30	31.05	1.12	1073	1203	439	-8.3	-13.3	-8.1
3 PM	2563.5	-1.32	31.06	1.12	1077	1199	439	-12.7	-12.8	-7.0
6 PM	2563.5	-1.33	31.08	1.12	1082	1194	439	-8.3	-11.7	-6.6
9 PM	2563.5	-1.32	31.10	1.12	1077	1199	439	-3.8	-10.7	-7.1
12 M	2563.5	-1.30	31.11	1.12	1073	1203	439	-8.2	-10.2	-8.1
3 AM	2563.5	-1.28	31.10	1.12	1077	1199	439	-12.6	-10.7	-9.2
6 AM	2563.5	-1.27	31.08	1.12	1082	1194	439	-8.2	-11.8	-9.6
9 AM	2563.5	-1.28	31.06	1.12	1077	1199	439	-3.8	-12.9	-9.2

4.3.2 ORBITAL MASS PROPERTIES VARIATION - EOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	1961.5	-1.53	30.53	1.47	1020	1171	412	-8.5	-13.1	-7.8
3 PM	1961.5	-1.56	30.55	1.47	1025	1167	412	-12.9	-12.7	-6.7
6 PM	1961.5	-1.57	30.57	1.47	1029	1162	412	-8.5	-11.6	-6.3
9 PM	1961.5	-1.55	30.60	1.47	1025	1167	412	-4.0	-10.5	-6.7
12 M	1961.5	-1.53	30.61	1.47	1021	1171	412	-8.4	-10.1	-7.8
3 AM	1961.5	-1.50	30.59	1.47	1025	1167	412	-12.8	-10.5	-8.9
6 AM	1961.5	-1.49	30.57	1.47	1029	1162	412	-8.4	-11.6	-9.3
9 AM	1961.5	-1.51	30.54	1.47	1025	1167	412	-4.0	-12.7	-8.9

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

1.3 CRITICAL MASS PROPERTIES

1.3.1 UPPER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.33	0.47
Y OFFSET FROM Z AXIS(IN.)	+2.0 TO 0.0	1.12	0.88
Z STATION	STA 30.7 TO STA 31.6	31.05	0.35
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	+0.2 TO -2.2	-1.57	0.63
Y OFFSET FROM Z AXIS(IN.)	+2.6 TO 0.0	1.47	1.13
Z STATION	STA 30.2 TO STA 31.3	30.53	0.33
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.29	0.11
Y TRAVEL(IN.)	0.6	0.34	0.26
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	-0.05	0.55
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	0.47	0.33
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	+25.0	-12.9	12.1
POXY(SLUG-FT2)	+25.0	-13.3	11.7
POZY(SLUG-FT2)	+15.0	-9.6	5.4
IXX (SLUG-FT2)	1150 (MAX)	1082.	68.
	800 (MIN)	1020.	220.
IYY (SLUG-FT2)	500 (MAX)	439.	61.
	300 (MIN)	412.	112.
IZZ (SLUG-FT2)	1300 (MAX)	1203.	97.
	900 (MIN)	1162.	262.

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

(bnFig. 15

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.4 ORBITAL MASS PROPERTIES VARIATION - LOWER SATELLITE

4.4.1 ORBITAL MASS PROPERTIES VARIATION - BOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2572.9	-1.26	31.04	1.15	1077	1208	443	-8.9	-12.5	-7.4
3 PM	2572.9	-1.28	31.05	1.15	1082	1204	443	-13.4	-12.1	-6.3
6 PM	2572.9	-1.29	31.07	1.15	1086	1199	443	-8.9	-11.0	-5.9
9 PM	2572.9	-1.28	31.09	1.15	1082	1204	443	-4.5	-9.9	-6.3
12 M	2572.9	-1.26	31.10	1.15	1077	1208	443	-8.9	-9.5	-7.4
3 AM	2572.9	-1.24	31.09	1.15	1082	1204	443	-13.3	-9.9	-8.5
6 AM	2572.9	-1.23	31.07	1.15	1086	1199	443	-8.8	-11.0	-8.9
9 AM	2572.9	-1.24	31.05	1.15	1082	1204	443	-4.4	-12.1	-8.5

4.4.2 ORBITAL MASS PROPERTIES VARIATION - EOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	1970.9	-1.48	30.52	1.50	1025	1176	416	-9.1	-12.4	-7.1
3 PM	1970.9	-1.50	30.53	1.50	1029	1172	416	-13.6	-11.9	-6.0
6 PM	1970.9	-1.51	30.56	1.50	1034	1167	416	-9.1	-10.8	-5.6
9 PM	1970.9	-1.50	30.58	1.50	1029	1172	416	-4.7	-9.7	-6.0
12 M	1970.9	-1.47	30.59	1.50	1025	1176	417	-9.1	-9.3	-7.1
3 AM	1970.9	-1.45	30.58	1.50	1029	1172	417	-13.5	-9.8	-8.2
6 AM	1970.9	-1.44	30.56	1.50	1034	1168	416	-9.0	-10.9	-8.6
9 AM	1970.9	-1.45	30.53	1.50	1029	1172	416	-4.6	-12.0	-8.2

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG. B

1.3 CRITICAL MASS PROPERTIES

1.3.2 LOWER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

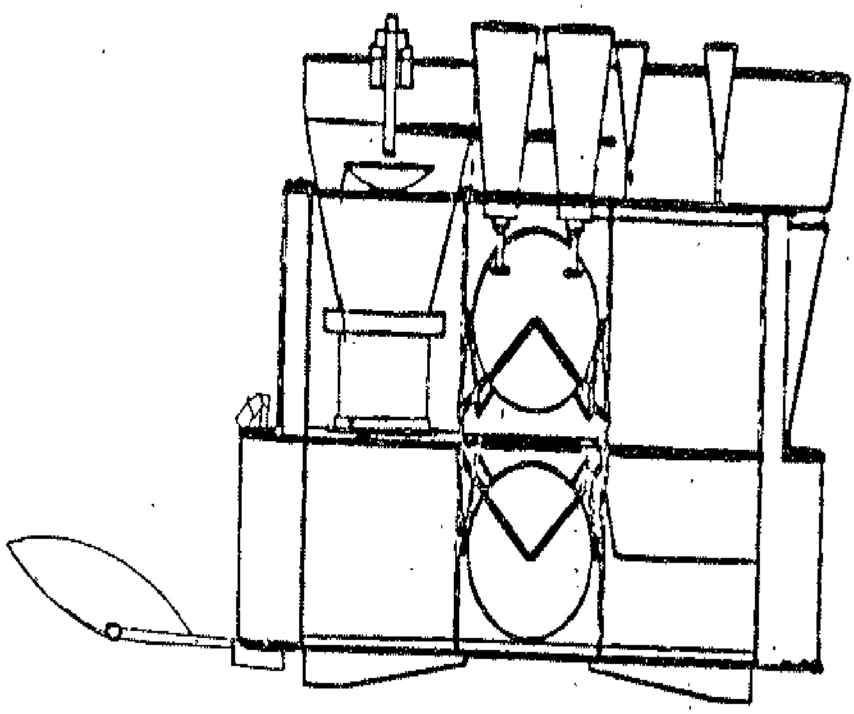
ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.29	0.51
Y OFFSET FROM Z AXIS(IN.)	+2.0 TO 0.0	1.15	0.85
Z STATION	STA 30.7 TO STA 31.6	31.04	0.34
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	+0.2 TO -2.2	-1.51	0.69
Y OFFSET FROM Z AXIS(IN.)	+2.6 TO 0.0	1.50	1.10
Z STATION	STA 30.2 TO STA 31.3	30.52	0.32
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.28	0.12
Y TRAVEL(IN.)	0.6	0.35	0.25
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	-0.04	0.56
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	0.48	0.32
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	+25.0	-13.6	11.4
POXY(SLUG-FT2)	+25.0	-12.5	12.5
POZY(SLUG-FT2)	+15.0	-8.9	6.1
IXX (SLUG-FT2)	1150 (MAX)	1086.	64.
	800 (MIN)	1025.	225.
IYY (SLUG-FT2)	500 (MAX)	443.	57.
	300 (MIN)	416.	116.
IZZ (SLUG-FT2)	1300 (MAX)	1208.	92.
	900 (MIN)	1167.	267.

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

4-15-93

CONFIG C

DRY WT/SC	1978.9 INCLUDES	
(4) 40W TWTA HEDD	56.9	
4) 10W HESCA	31.2	
(2) 10W TWTA HEDD	14.6	
(2) GDA	49.2	
(4) TANTALUM SHLDS	6.3	
88 NEW SOLAR ARRAY w/"CIC" CELLS	129.7	
NEW CB STRUCT	177.5	
NEW ACE	50.9	
NEW FEED HORN/REFL	6.9	
(2) MULTIMODE EC ANT	14.0	
(2) 19 MBA'S	132.0	



Configuration C

Config C.

4.0 SEQUENTIAL MASS PROPERTIES DATA

4.1 PAYLOAD LAUNCH TO PAYLOAD SEPARATION

ITEM MISSION EVENT	WEIGHT (LBS.)	CENTER OF MASS INCHES			MOMENTS OF INERTIA SLUG FT2			PRODUCTS OF INERTIA SLUG FT2		
	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
PAYLOAD LAUNCH MODULE DSCS III/II	5241.2	-0.0	-0.6	1.0	2315.	1434.	2051.	-41.2	-0.8	-2.3
UPSC IB DSCS III SEPARATED	2593.4	-1.4	30.8	1.0	594.	698.	459.	4.1	-10.6	-8.9
LWSC IB DSCS III + ADAPTER	2647.8	1.4	-31.4	1.0	624.	734.	493.	3.9	9.8	7.7
LWSC IB DSCS III SEPARATED	2602.8	1.4	-30.8	1.0	598.	704.	464.	3.4	9.8	8.2
ADAPTER DSCS III	45.1	-0.0	-66.1	3.0	14.	30.	18.	0.0	-0.0	0.1

4.2 SEQUENTIAL MASS PROPERTIES DATA - PAYLOAD BOM THROUGH PAYLOAD EOM

4.2.1 UPPER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
UPSC IB GE REF GA S SEP SA STOWED	2593.4	-1.4	30.8	1.0	594.	698.	459.	4.1	-10.6	-8.9
UPSC IB GE REF GA S SEP SA DEPLOYED	2593.4	-1.4	30.4	1.0	1086.	1207.	443.	3.8	-11.2	-8.7
UPSC IB GE REF BOL GA&SA DEP	2593.4	-1.9	30.4	1.0	1092.	1236.	468.	12.7	-9.7	-8.6
UPSC IB GE REF EOL GA&SA DEP	1991.4	-2.4	29.7	1.3	1039.	1204.	440.	12.2	-9.5	-8.2

4.2.2 LOWER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
LWSC IB DSCS III SEPARATED	2602.8	-1.4	30.8	1.0	598.	704.	464.	3.4	-9.8	-8.2
LWSC IB GDA STOWED ARY DEPLOYED	2602.8	-1.4	30.4	1.0	1091.	1212.	447.	3.1	-10.5	-7.9
LWSC IB GDA DEPLOYE ARY DEPLOYED	2602.8	-1.9	30.4	1.0	1097.	1241.	472.	12.1	-8.9	-7.8
LWSC IB AT PROPELLA DEPLETION	2000.8	-2.3	29.7	1.3	1044.	1209.	445.	11.6	-8.7	-7.4

COORDINATE REFERENCE AXES ARE SHOWN IN SECTION 5.1

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.3 ORBITAL MASS PROPERTIES VARIATION - UPPER SATELLITE

4.3.1 ORBITAL MASS PROPERTIES VARIATION - BOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2593.4	-1.94	30.40	0.96	1092	1236	467	12.7	-9.7	-8.6
3 PM	2593.4	-1.96	30.41	0.96	1097	1231	467	8.3	-9.2	-7.5
6 PM	2593.4	-1.97	30.43	0.96	1101	1227	468	12.7	-8.1	-7.0
9 PM	2593.4	-1.96	30.45	0.96	1097	1231	468	17.2	-7.1	-7.5
12 M	2593.4	-1.94	30.46	0.96	1093	1236	468	12.8	-6.6	-8.6
3 AM	2593.4	-1.92	30.45	0.96	1097	1231	468	8.4	-7.1	-9.7
6 AM	2593.4	-1.91	30.43	0.96	1101	1227	468	12.8	-8.2	-10.1
9 AM	2593.4	-1.92	30.41	0.96	1097	1231	468	17.2	-9.2	-9.6

4.3.2 ORBITAL MASS PROPERTIES VARIATION - EOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	1991.4	-2.36	29.69	1.25	1039	1204	440	12.2	-9.5	-8.2
3 PM	1991.4	-2.38	29.71	1.25	1044	1199	440	7.7	-9.0	-7.1
6 PM	1991.4	-2.39	29.73	1.25	1048	1195	440	12.2	-7.9	-6.7
9 PM	1991.4	-2.38	29.76	1.25	1044	1199	440	16.6	-6.8	-7.1
12 M	1991.4	-2.36	29.77	1.25	1040	1204	440	12.3	-6.4	-8.2
3 AM	1991.4	-2.33	29.75	1.25	1044	1199	440	7.9	-6.9	-9.3
6 AM	1991.4	-2.32	29.73	1.25	1048	1195	440	12.3	-7.9	-9.7
9 AM	1991.4	-2.33	29.70	1.25	1044	1199	440	16.7	-9.0	-9.3

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG C

1.3 CRITICAL MASS PROPERTIES

1.3.1 UPPER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.97	-0.17
Y OFFSET FROM Z AXIS(IN.)	+2.0 TO 0.0	0.96	0.96
Z STATION	STA 30.7 TO STA 31.6	30.40	-0.30
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	+0.2 TO -2.2	-2.39	-0.19
Y OFFSET FROM Z AXIS(IN.)	+2.6 TO 0.0	1.25	1.25
Z STATION	STA 30.2 TO STA 31.3	29.69	-0.51
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.48	-0.08
Y TRAVEL(IN.)	0.6	0.29	0.29
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	0.60	0.00
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	1.31	-0.51
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	+25.0	16.7	8.3
POXY(SLUG-FT2)	+25.0	-9.7	15.3
POZY(SLUG-FT2)	+15.0	-10.1	4.9
IXX (SLUG-FT2)	1150 (MAX)	1101.	49.
	800 (MIN)	1039.	239.
IYY (SLUG-FT2)	500 (MAX)	468.	32.
	300 (MIN)	440.	140.
IZZ (SLUG-FT2)	1300 (MAX)	1236.	64.
	900 (MIN)	1195.	295.

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG C

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.4 ORBITAL MASS PROPERTIES VARIATION - LOWER SATELLITE

4.4.1 ORBITAL MASS PROPERTIES VARIATION - BOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2602.8	-1.90	30.40	0.99	1097	1241	472	12.1	-8.9	-7.8
3 PM	2602.8	-1.92	30.40	0.99	1101	1236	472	7.6	-8.4	-6.8
6 PM	2602.8	-1.92	30.42	0.99	1106	1232	472	12.1	-7.3	-6.3
9 PM	2602.8	-1.92	30.44	0.99	1101	1237	472	16.5	-6.3	-6.8
12 M	2602.8	-1.90	30.45	0.99	1097	1241	472	12.2	-5.8	-7.9
3 AM	2602.8	-1.88	30.44	0.99	1101	1237	472	7.8	-6.3	-9.0
6 AM	2602.8	-1.87	30.42	0.99	1106	1232	472	12.2	-7.4	-9.4
9 AM	2602.8	-1.88	30.40	0.99	1101	1237	472	16.6	-8.5	-8.9

4.4.2 ORBITAL MASS PROPERTIES VARIATION - EOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2000.8	-2.30	29.69	1.29	1044	1209	445	11.6	-8.7	-7.4
3 PM	2000.8	-2.33	29.70	1.29	1048	1204	445	7.1	-8.2	-6.4
6 PM	2000.8	-2.33	29.72	1.29	1053	1200	445	11.5	-7.1	-5.9
9 PM	2000.8	-2.32	29.75	1.29	1048	1204	445	16.0	-6.0	-6.4
12 M	2000.8	-2.30	29.76	1.29	1044	1209	445	11.6	-5.6	-7.5
3 AM	2000.8	-2.27	29.75	1.29	1048	1205	445	7.3	-6.1	-8.6
6 AM	2000.8	-2.26	29.72	1.29	1053	1200	445	11.7	-7.2	-9.0
9 AM	2000.8	-2.27	29.70	1.29	1048	1205	445	16.1	-8.2	-8.5

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG C

1.3 CRITICAL MASS PROPERTIES

1.3.2 LOWER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.92	-0.12
Y OFFSET FROM Z AXIS(IN.)	+2.0 TO 0.0	0.99	0.99
Z STATION	STA 30.7 TO STA 31.6	30.40	-0.30
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	+0.2 TO -2.2	-2.33	-0.13
Y OFFSET FROM Z AXIS(IN.)	+2.6 TO 0.0	1.29	1.29
Z STATION	STA 30.2 TO STA 31.3	29.69	-0.51
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.47	-0.07
Y TRAVEL(IN.)	0.6	0.30	0.30
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	0.60	-0.00
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	1.31	-0.51
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	+25.0	16.1	8.9
POXY(SLUG-FT2)	+25.0	-8.9	16.1
POZY(SLUG-FT2)	+15.0	-9.4	5.6
IXX (SLUG-FT2)	1150 (MAX)	1106.	44.
	800 (MIN)	1044.	244.
IYY (SLUG-FT2)	500 (MAX)	472.	28.
	300 (MIN)	445.	145.
IZZ (SLUG-FT2)	1300 (MAX)	1241.	59.
	900 (MIN)	1200.	300.

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

4-25-86

CONFIG D

	DRY WT / SC	1916.3 INCLUDES
(4)	40W TWTA HEDD	56.8
(4)	10W HESLA	31.2
2	10W TWTA HEDD	14.6
2)	SDA	49.2
4	310 TANTALUM SHLDS	6.3
	B8 SOLAR ARRY W/O CR	129.7
	B8 CR UNDCTURE	177.5
	B9 ACE W/O NEW SHLD	50.9
1	19 MBA	65.0
2	MULTIMODE ER ANT	14.0
1	NEW KIDNEY ANT	10.3 * REVISED FROM 6.9

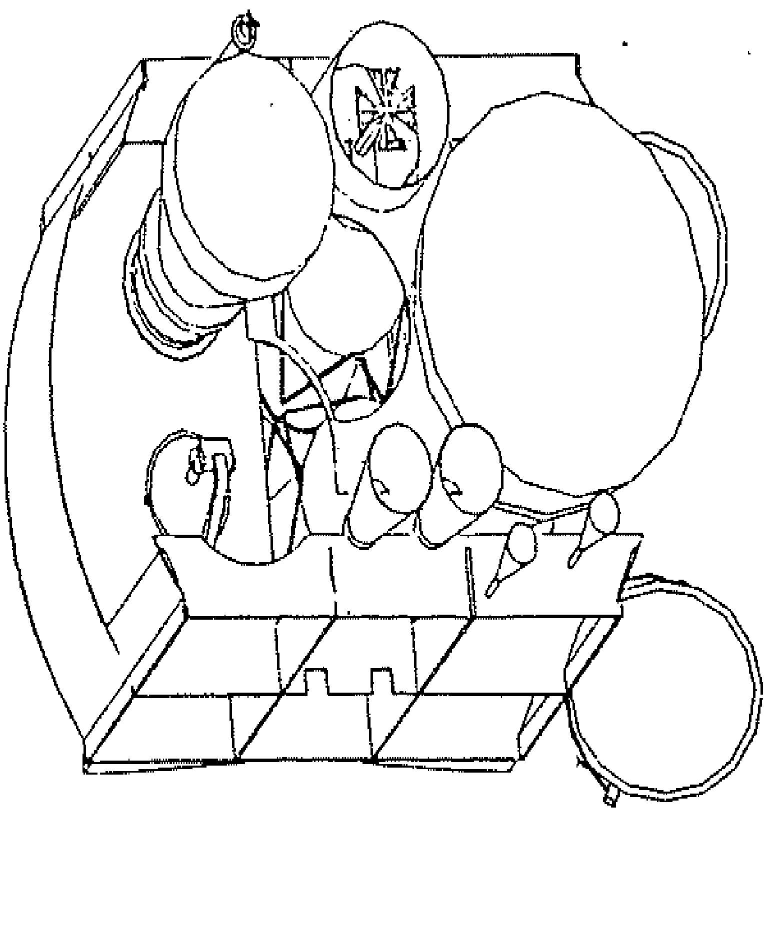
System assembly

UNITS=IN

ENTITY: NGPM - NEW FEEDHORNS

VIEW: 103 - VIEW103 SYSTEM DISPLAY

DISPLAY: 1 - HARD SHADE



CONFIGURATION D

CONFIG D 4/25/86

4.0 SEQUENTIAL MASS PROPERTIES DATA

4.1 PAYLOAD LAUNCH TO PAYLOAD SEPARATION

ITEM MISSION EVENT	WEIGHT (LBS.)	CENTER OF MASS INCHES			MOMENTS OF INERTIA SLUG FT2			PRODUCTS OF INER SLUG FT2		
	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
PAYLOAD LAUNCH MODULE DSCS III/II	5116.8	-0.0	-0.6	1.4	2230.	1401.	1953.	-2.4	-0.8	-2.0
UPSC IB DSCS III SEPARATED	2530.8	-0.8	30.3	1.4	581.	682.	440.	11.6	-16.9	-3.8
LWSC IB DSCS III + ADAPTER	2586.0	0.7	-31.0	1.4	611.	718.	475.	11.2	16.[illegible]	2.7
LWSC IB DSCS III SEPARATED	2540.9	0.7	-30.3	1.4	585.	688.	445.	11.0	16.1	3.1
ADAPTER DSCS III	45.1	-0.0	-66.1	3.0	14.	30.	18.	0.0	-0.0	0.1

4.2 SEQUENTIAL MASS PROPERTIES DATA - PAYLOAD BOM THROUGH PAYLOAD EOM

4.2.1 UPPER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
UPSC IB GE REF GA S SEP SA STOWED	2530.8	-0.8	30.3	1.4	581.	682.	440.	11.6	-16.9	-
UPSC IB GE REF GA S SEP SA DEPLOYED	2530.8	-0.8	29.9	1.4	1073.	1191.	424.	11.4	-17.6	-3.4
UPSC IB GE REF BOL GA&SA DEP	2530.8	-1.3	29.9	1.4	1079.	1220.	449.	20.2	-15.9	-3.3
UPSC IB GE REF EOL GA&SA DEP	1928.8	-1.5	29.0	1.8	1025.	1188.	421.	19.9	-15.7	-2.7

4.2.2 LOWER SATELLITE

ITEM MISSION EVENT	W	X	Z	Y	IOX	IOZ	IOY	POXZ	POXY	POYZ
LWSC IB DSCS III SEPARATED	2540.9	-0.7	30.3	1.4	585.	688.	445.	11.0	-16.1	-3.1
LWSC IB GDA STOWED ARY DEPLOYED	2540.9	-0.7	29.9	1.4	1077.	1197.	428.	10.8	-16.7	-2.7
LWSC IB GDA DEPLOYE ARY DEPLOYED	2540.9	-1.3	29.9	1.4	1083.	1225.	454.	19.6	-15.0	-2.6
LWSC IB AT PROPELLA DEPLETION	1938.9	-1.5	29.0	1.8	1030.	1193.	426.	19.3	-14.9	-1.9

COORDINATE REFERENCE AXES ARE SHOWN IN SECTION 5.1

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.3 ORBITAL MASS PROPERTIES VARIATION - UPPER SATELLITE

4.3.1 ORBITAL MASS PROPERTIES VARIATION - BOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2530.8	-1.29	29.90	1.38	1079	1220	449	20.2	-15.9	-3.3
3 PM	2530.8	-1.31	29.91	1.38	1083	1216	449	15.8	-15.4	-2.3
6 PM	2530.8	-1.32	29.93	1.38	1088	1211	449	20.2	-14.3	-1.8
9 PM	2530.8	-1.31	29.95	1.38	1084	1216	449	24.7	-13.2	-2.3
12 M	2530.8	-1.29	29.95	1.38	1079	1220	449	20.3	-12.8	-3.4
3 AM	2530.8	-1.27	29.94	1.38	1084	1216	449	15.9	-13.3	-4.5
6 AM	2530.8	-1.26	29.92	1.38	1088	1211	449	20.3	-14.4	-4.9
9 AM	2530.8	-1.27	29.90	1.38	1083	1216	449	24.7	-15.4	-4.4

4.3.2 ORBITAL MASS PROPERTIES VARIATION - EOM - UPPER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	1928.8	-1.52	29.00	1.81	1025	1188	421	19.9	-15.7	-2.7
3 PM	1928.8	-1.55	29.02	1.81	1030	1184	421	15.4	-15.2	-1.6
6 PM	1928.8	-1.56	29.04	1.81	1035	1179	421	19.8	-14.1	-1.2
9 PM	1928.8	-1.54	29.07	1.81	1030	1184	422	24.3	-13.1	-1.6
12 M	1928.8	-1.52	29.08	1.81	1026	1188	422	19.9	-12.6	-2.7
3 AM	1928.8	-1.49	29.07	1.81	1030	1184	422	15.6	-13.1	-3.8
6 AM	1928.8	-1.48	29.04	1.81	1035	1179	421	20.0	-14.2	-4.2
9 AM	1928.8	-1.49	29.01	1.81	1030	1184	421	24.4	-15.3	-3.7

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG D
4/25/86

1.3 CRITICAL MASS PROPERTIES

1.3.1 UPPER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.32	0.48
Y OFFSET FROM Z AXIS(IN.)	+2.0 TO 0.0	1.38	0.62
Z STATION	STA 30.7 TO STA 31.6	29.90	-0.80
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	-0.2 TO -2.2	-1.56	0.64
Y OFFSET FROM Z AXIS(IN.)	+2.6 TO 0.0	1.81	0.79
Z STATION	STA 30.2 TO STA 31.3	29.00	-1.20
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.29	0.11
Y TRAVEL(IN.)	0.6	0.43	0.17
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	1.10	-0.50
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	2.00	-1.20
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	±25.0	24.4	0.6
POXY(SLUG-FT2)	±25.0	-15.9	9.1
POZY(SLUG-FT2)	±15.0	-4.9	10.1
IXX (SLUG-FT2)	1150 (MAX)	1088.	62.
	800 (MIN)	1025.	225.
IYY (SLUG-FT2)	500 (MAX)	449.	51.
	300 (MIN)	421.	121.
IZZ (SLUG-FT2)	1300 (MAX)	1220.	80.
	900 (MIN)	1179.	279.

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG D
4/25/86

4.0 SEQUENTIAL MASS PROPERTIES DATA - CONTINUED

4.4 ORBITAL MASS PROPERTIES VARIATION - LOWER SATELLITE

4.4.1 ORBITAL MASS PROPERTIES VARIATION - BOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	2540.9	-1.26	29.89	1.40	1083	1225	454	19.6	-15.0	-2.6
3 PM	2540.9	-1.28	29.90	1.40	1088	1221	454	15.2	-14.6	-1.5
6 PM	2540.9	-1.28	29.92	1.40	1092	1217	454	19.6	-13.5	-1.1
9 PM	2540.9	-1.27	29.94	1.40	1088	1221	454	24.1	-12.4	-1.6
12 M	2540.9	-1.25	29.94	1.40	1084	1225	454	19.7	-12.0	-2.6
3 AM	2540.9	-1.23	29.93	1.40	1088	1221	454	15.3	-12.4	-3.7
6 AM	2540.9	-1.23	29.91	1.40	1092	1217	454	19.7	-13.5	-4.2
9 AM	2540.9	-1.24	29.89	1.40	1088	1221	454	24.1	-14.6	-3.7

4.4.2 ORBITAL MASS PROPERTIES VARIATION - EOM - LOWER SATELLITE

ORBIT POSITION	W	X	Z	Y	IX	IZ	IY	PXZ	PXY	PYZ
12 N	1938.9	-1.47	29.00	1.84	1030	1193	426	19.3	-14.9	-1.9
3 PM	1938.9	-1.50	29.01	1.84	1034	1189	426	14.8	-14.4	-0.8
6 PM	1938.9	-1.51	29.04	1.84	1039	1185	426	19.2	-13.3	-0.4
9 PM	1938.9	-1.50	29.06	1.84	1034	1189	426	23.7	-12.2	-0.9
12 M	1938.9	-1.47	29.07	1.84	1030	1193	426	19.3	-11.8	-2.0
3 AM	1938.9	-1.44	29.06	1.84	1034	1189	426	15.0	-12.3	-3.1
6 AM	1938.9	-1.43	29.03	1.84	1039	1185	426	19.4	-13.4	-3.5
9 AM	1938.9	-1.45	29.01	1.84	1034	1189	426	23.8	-14.4	-3.0

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

CONFIG D
4/25/86

1.3 CRITICAL MASS PROPERTIES

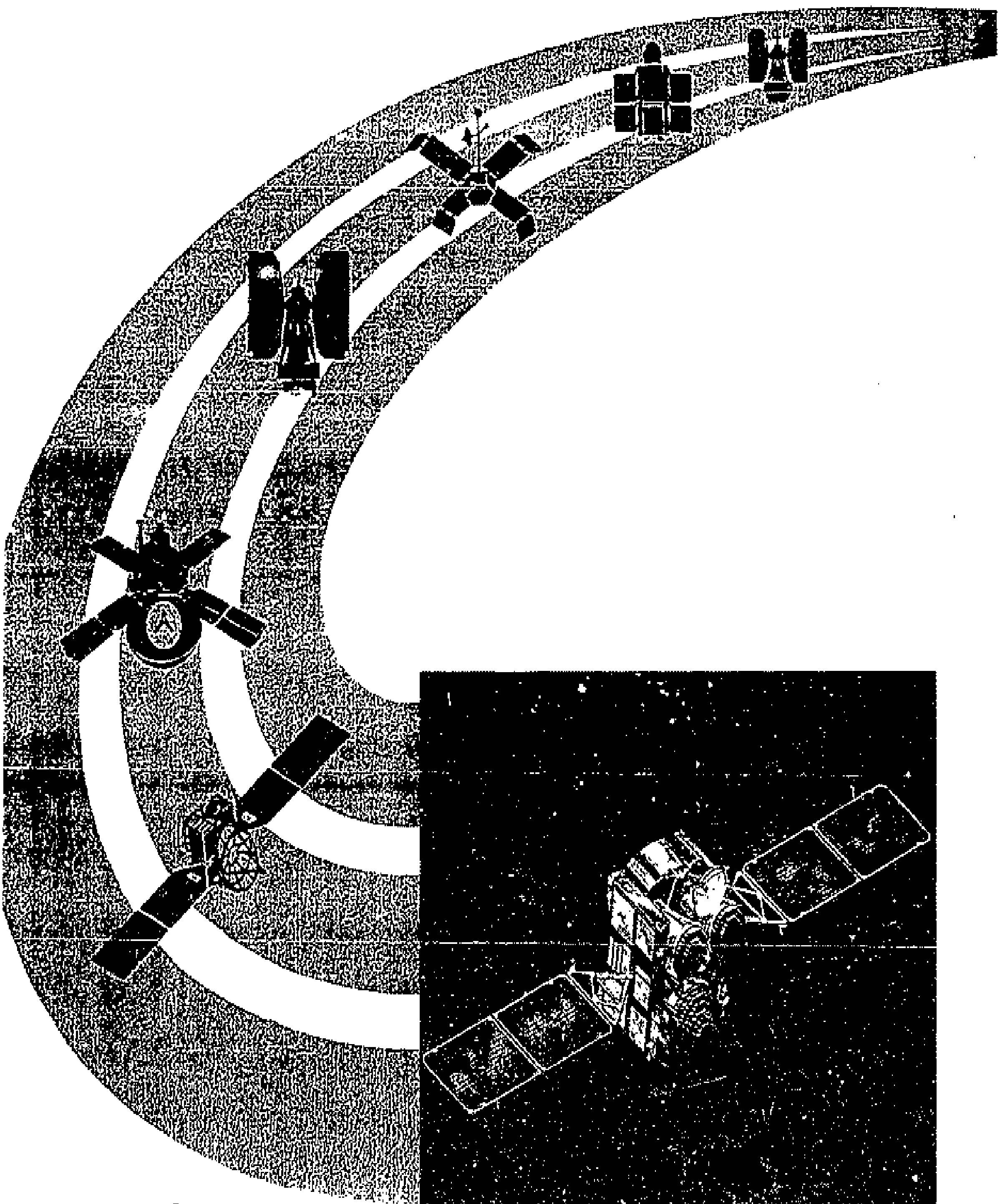
1.3.2 LOWER SPACECRAFT

THE FOLLOWING ARE THE CRITICAL MASS PROPERTIES OF THE DSCS III SPACECRAFT IN THE ORBIT MODE WITH GDA & ARRAY DEPLOYED AS SPECIFIED IN SVS 9355X30

ITEM	REQUIRED	CURRENT	MARGIN
CENTER OF MASS OFFSETS - BOM			
X OFFSET FROM Z AXIS(IN.)	0.0 TO -1.8	-1.28	0.52
Y OFFSET FROM Z AXIS(IN.)	-2.0 TO 0.0	1.40	0.60
Z STATION	STA 30.7 TO STA 31.6	29.89	-0.81
CENTER OF MASS OFFSETS - EOM			
X OFFSET FROM Z AXIS(IN.)	+0.2 TO -2.2	-1.51	0.69
Y OFFSET FROM Z AXIS(IN.)	-2.6 TO 0.0	1.84	0.76
Z STATION	STA 30.2 TO STA 31.3	29.00	-1.20
CENTER OF MASS TRAVEL			
X TRAVEL(IN.)	0.4	0.28	0.12
Y TRAVEL(IN.)	0.6	0.44	0.16
Z TRAVEL(IN.) BOM TO STA 31.0	0.6	1.11	-0.51
Z TRAVEL(IN.) EOM FROM STA 31.0	0.8	2.00	-1.20
MOMENTS AND PRODUCTS OF INERTIAS			
POXZ(SLUG-FT2)	±25.0	23.8	1.2
POXY(SLUG-FT2)	±25.0	-15.0	10.0
POZY(SLUG-FT2)	±15.0	-4.2	10.8
IXX (SLUG-FT2)	1150 (MAX)	1092.	58.
	800 (MIN)	1030.	230.
IYY (SLUG-FT2)	500 (MAX)	454.	46.
	300 (MIN)	426.	126.
IZZ (SLUG-FT2)	1300 (MAX)	1225.	75.
	900 (MIN)	1185.	285.

MOMENTS AND PRODUCTS OF INERTIA ARE REFERENCED TO A COORDINATE AXES PASSING THROUGH THE RESPECTIVE CENTER OF MASS AND PARALLEL TO THE REFERENCE AXES SHOWN IN SECTION 5.2

DEFENSE SATELLITE COMMUNICATIONS SYSTEM



GENERAL ELECTRIC

SPACE SYSTEMS DIVISION